Report No. UT- 05.11

DEVELOPMENT OF A USER COST ESTIMATION PROCEDURE FOR WORK ZONES

DRAFT FINAL REPORT

Prepared For:

Utah Department of Transportation Research and Development Division

Submitted By:

Brigham Young University
Department of Civil & Environmental Engineering

June 2005

UDOT RESEARCH & DEVELOPMENT REPORT ABSTRACT

1. Report No. UT – 05.11	**2. Government Accession No.**	**3. Recipients Catalog No.**
4. Title and Subtitle **DEVELOPMENT OF A USER COST ESTIMATION PROCEDURE FOR WORK ZONES**	5. Report Date June 2005 **6. Performing Organization Code**	
7. Author(s) Mitsuru Saito, Ph.D., P.E., Michael R. Adams, EIT Thomas G. Jin	**8. Performing Organization Report No.**	
9. Performing Organization Name and Address Brigham Young University, Civil & Environ. Eng. Provo, UT 84602	**10. Work Unit No.** **11. Contract No.**	
12. Sponsoring Agency Name and Address Utah Department of Transportation 4501 South 2700 West Salt Lake City, UT 84119-5998	**13. Type of Report and Period Covered** Final Report, December 2003 – June 2005 **14. Sponsoring Agency Code**	

15. Supplementary Notes
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16. Abstract

Work zones associated with highway construction projects create localized bottlenecks where the average traffic speed is reduced and queues are formed, thus causing increased costs as a result of the additional time and fuel needed to traverse the work zone. These user costs can be estimated and applied as a form of incentive to the contractor to complete the work sooner, thus allowing traffic to return to the free-flow speed. Methods to determine user costs are explored through a literature search, questionnaire survey of other state highway agencies, and interviews with employees of the Utah Department of Transportation (UDOT).

The literature search found reports on how other states have employed user costs and how they derived the time values used in their methods. Proper planning and preparation is essential to ensure that the methods and values used are appropriate and justifiable.

The questionnaire survey indicated that the most popular methods for user cost estimation would be simple and easy to use. The value of time should be estimated using the average wage of the state. Lost time or delay should be calculated using the extra time associated with reduced vehicle speeds through the work zone. Engineer's discretion should be allowed in adjusting determined user cost value.

The results of the interviews indicated that the ease of use would be a major quality desired by UDOT employees for a user cost plan. Similar to other state agencies, delay costs should be based on the speed reduction through the work zone. Vehicle operating costs should be based on the cost of fuel. Other factors to use for calculations should include the AADT, length of the work zone, number of closed lanes, the day and time of the closure, the percentage of automobiles and trucks, and the functional class of the facility. Any computer programs should be intuitive and easy to use.

Four computer programs were evaluated: MicroBENCOST, QuickZone, DelayE, and DUCK. Each haw strengths and weaknesses, but DelayE and DUCK encompass the ideals desired by UDOT employees for determining user costs. DUCK and DelayE are recommended for use by UDOT because the combination of the two provides UDOT with the desired attributes mentioned previously. The Microsoft Excel based DUCK program was created especially for UDOT in this study using the objectives UDOT employees provided in mind.

It is recommended that the benefits of QuickZone be restudied now that its second version became available in May 2005. It is also recommended to develop a shell program to control both DUCK and DelayE for easier use.

17. Key Words Work zone, Delay estimation, User cost estimation		**18. Distribution Statement** No Restrictions. Available from: Utah Department of Transportation Research Division Box 148410 Salt Lake City, Utah 84114-8410 Brigham Young University Department of Civil and Environmental Engineering 368CB Provo, Utah 84602	
19. Security Classification (For this report) None	**20. Security Classification (For this page)** None	**21. No. of Pages**	**22. Price**

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ACKNOWLEDGEMENTS

This research was made possible with funding from the Federal Highway Administration, the Utah Department of Transportation, and Brigham Young University.

Special thanks to the following people at the Utah Department of Transportation (UDOT). Additional thanks to everyone else at UDOT who helped the researchers to complete this study.

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Chapter 1. Introduction

Throughout the freeway and arterial systems in Utah and throughout the United States, thousands of people travel every day to various destinations. Over the years, streets and highways need repair or replacement, and this can only be accomplished by construction of some sort. Construction comes at a price, not only for the actual construction, but for those drivers who pass through the construction zone. Slower speeds increase the travel time and the amount of fuel consumed by drivers waiting in slower traffic. User costs are those additional costs incurred by a driver having to drive slower, spend time in a queue, or take a detour compared to the normal, free-flow speed.

This study focuses on user costs and develops a procedure to quantify such costs to be used as an incentive for contractors to achieve faster completion times, thus reducing the amount of time contractors remain on the road. Using the value of user costs as an incentive to the contractors may encourage them to formulate new and innovative construction methods that will enable contractors to complete work in fewer days than by normal construction methods.

1.1 Past Practice

In the past, the Utah Department of Transportation (UDOT) has not had a documented, formal, and universal format for all employees to use when determining user costs if incentives were used on a project. One method used was to ask one of the engineers in planning, who had a general knowledge of determining user costs, to produce a value that would be reasonable for UDOT to use. If this was not done, then a value which seemed reasonable for both UDOT and the contractor was used. UDOT has requested an uncomplicated method that the engineers in any regional office may use that will provide a value that is reasonable and justifiable in a legal disagreement.

1.2 Objectives

The objectives of this study are to accomplish the following:

- Examine how other states determine user costs.
- Evaluate what features are desired by UDOT engineers for a simple method to determine user costs.
- Review available software and computer programs.
- Develop a plan for use by UDOT.

The first task of this research was to conduct a literature review to learn what other states have accomplished and how they determine user costs. Second, information was gathered from UDOT personnel to understand what they expect from such a system. Third, a number of computer programs available to assist in determining the costs involved with traffic demand, capacity, and work zones were examined. A spreadsheet

named DUCK, created especially for UDOT to assist in user cost calculations, is presented. Finally, a flow chart was prepared to instruct UDOT employees about how to use DUCK and DelayE to determine user costs.

1.3 Organization of Thesis

There are nine chapters in this study. Chapter 1 explains the topic and describes what is accomplished. Chapter 2 focuses on studies conducted by other researchers and methods described for determining user costs. Actual values used by some states are also given in the chapter. Chapter 3 summarizes the costs and methods 13 state transportation departments use to determine the total user costs. Chapter 4 explains what engineers from UDOT desire from a department-wide system of user cost calculations and what they think would be most useful for determining those costs. Chapter 5 reviews four programs that may be used for determining user costs. Chapter 6 presents a plan, or flowchart, for engineers and employees at UDOT to use for the purpose of determining user costs. Chapter 7 reviews and describes how to use the programs DUCK and DelayE in determining user costs. Chapter 8 shows a sample problem and how to solve it using DUCK and DelayE. Chapter 9 provides a final summary of the study.

Chapter 2. Literature Search

Various reports and studies have been conducted on the topic of user costs and methods to apply them as charges to reduce the negative impacts of work zones and lane closures. First, general procedures for deciding when user costs may be useful and methods to determine them are discussed. The second section discusses specific items to consider when determining user costs. The third section presents actual values used by a sample of states in their user cost calculations. The fourth section focuses on recommendations for adjusting the user cost value to be charged as an incentive.

2.1 General Procedure

A state highway agency (SHA) needs to have a plan or procedure to follow before beginning the process of charging a contractor for the user cost of a roadway. The reason for having a plan is stated by Gillespie to the Virginia Department of Transportation (VDOT) when he said, "By following no standard procedure in calculating incentive/disincentive (I/D) amounts, VDOT may run the risk of seeing a tardy contractor challenge and invalidate the I/D clause in one of its contracts in court" (Gillespie 1998).

2.1.1 User Cost Estimation Plan

A plan must be set forth to determine the user costs, and there should be a process to determine if and when user costs should be considered for use and how to apply that decision. Daniels displays a flowchart for the process of estimating road user costs (RUC) as shown in Figure 2-1 (Daniels et al. 1999).

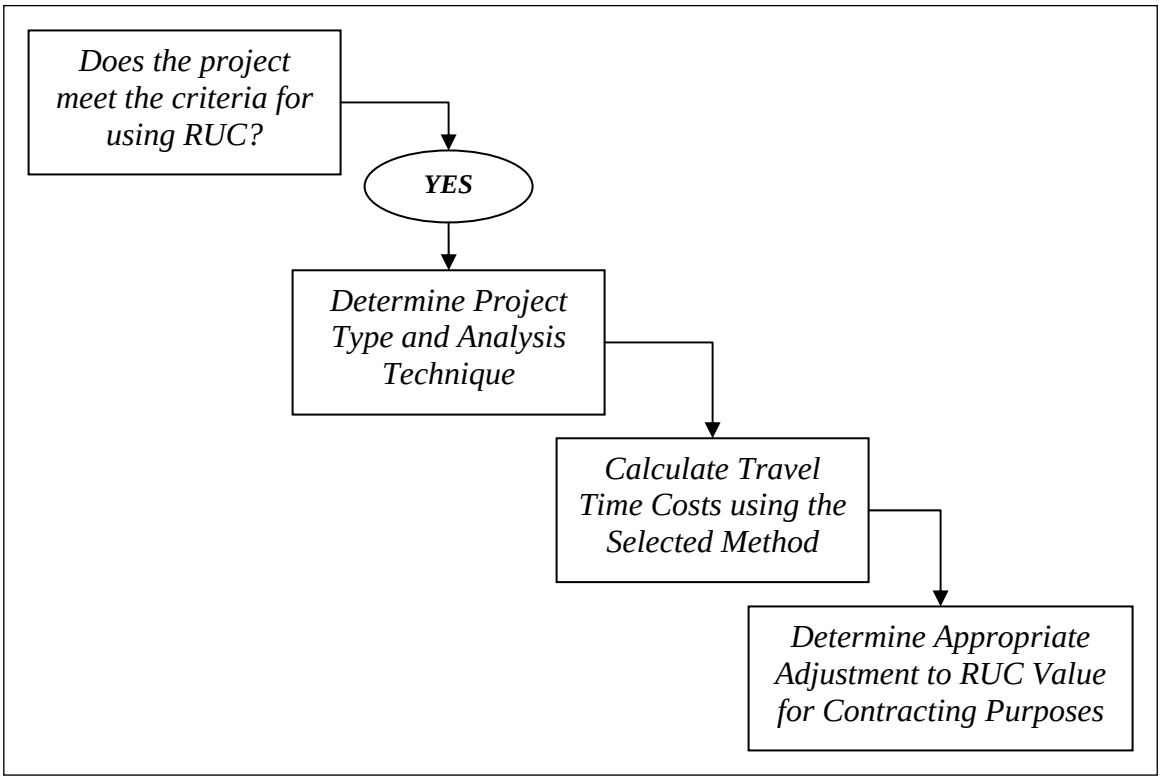


Figure 2-1: Procedure for Estimating RUC.

This figure shows an overall view of the process for determining user costs. Developing user cost estimates needs to be done correctly, and any state-wide method should entail the following characteristics and properties (Gillespie 1998):

- Rigorous and accurate.
- Easy to understand and apply.
- Convenient by “piggybacking” on existing project activities and available data.
- Applicable to a high proportion of cases.

A standard method applied by a state should be rigorous and accurate in order to be upheld in court, if needed. The method should also provide both the SHA and the contractor an understanding of how the agreed-upon user cost has been formulated. A standard method should be easy to understand for the various users. The engineers should understand the basic concepts behind the method and know how to determine the user cost estimate quickly and easily. The method ought to be simple enough to use so SHA engineers will be willing to use it. To save on costs, the designed method should use available data already collected. Any chosen method should be applicable to a high proportion of projects for ease of use and to provide consistent results throughout the state.

2.1.2 User Cost Contracting Methods

Three main methods are used to provide an incentive to the contractor to expedite the completion or minimize user impacts of a project. These include the following:

- Incentive/disincentive (I/D).
- Cost/time or A+B.
- Lane rental.

Each of these methods has their pros and cons and, therefore, each is used for specific types of projects.

The I/D method penalizes the contractor if the project is not finished by the completion date, but the contractor may receive an incentive for completing a project early. The I/D method must have both the incentive and the disincentive. One positive feature of an I/D method concerns legal challenges because this method allows both a charge for a failure to complete on time and a reward for early completion. Gillespie reports "Legal research indicates that a disincentive provision combined with an incentive is less vulnerable to legal challenge" (Gillespie 1998). On the other side, though, "The major objective is that [the I/D method] is literally based on the contract time as determined by the owner….[and is], in most cases, determined on the high side. Contractors are easily able to save some contract time that was generous…from the beginning" (Herbsman and Glacola 1998). Three years earlier, Herbsman concluded that the I/D method was the least effective and most expensive overall method (Herbsman et al. 1995).

The cost/time or A+B method invites the bidding contractors to provide a bid for the project cost plus the amount of time planned to complete the project. Ideally, the contractor with the lowest bid and earliest completion time would be awarded the project. The A+B method was found to be the most economical (Herbsman et al. 1995) and is receiving more support than it did in the past (Herbsman and Glacola 1998). The A+B method may be used in conjunction with the I/D clause to improve the enforceability of the completion date by ensuring that the contractor is responsible for the completion date given in the bidding process (Gillespie 1998).

Lane rental is the third method to apply user costs. This method requires that the contractor be charged for the time that the lane is closed to traffic. Herbsman and Glagola describe lane rental in this way (Herbsman and Glacola 1998):

> "The contractor will be charged for each time lanes were closed based on the predetermined fees that were part of the bidding documents. The time interval can be weeks, days, hours, or even smaller intervals….The contractor must determine the future cost for lane closure and incorporate it into his/her cost estimate."

The SHA must provide the costs for closing the lanes. The costs are normally determined by taking into account the day of the week, time of day, annual average daily traffic (AADT), percentage of trucks, and any other possible parameters. The SHA decides how detailed to make the list of costs, but all values should be reasonable and justifiable.

2.1.3 When to Apply User Costs

User costs may be applied to many projects, but Daniels et al. (1999) stated that the main criterion for applying user costs to a project come when:

- Capacity is added.
- Economic impacts are expected.
- Rehabilitation is in very high traffic areas.

User costs may be applied when any of these three criteria are met due to the time sensitivity of the project. The sooner capacity is added, the sooner travel time and the cost of traveling should be reduced. Negative economic impacts may be created if a project affects access to businesses, thus possibly decreasing sales and upsetting

merchants. For example, full-surface pavement rehabilitation projects close a large portion of the street surface and may greatly affect traffic on the street. The sooner these projects are completed, the sooner traffic flow will improve.

According to the Michigan Department of Transportation (MDOT), applying an incentive and disincentive to a project should occur when the following conditions occur (Gillespie 1998):

- Substantial user cost savings can be realized.
- Total additional user costs are expected to be at least 5 percent of the project cost, with $5,000 considered the daily minimum for major projects.
- An expedited construction schedule can compress the duration of traffic restriction by at least 15 days.
- Traffic capacity will be reduced below an acceptable level of service (LOS) and no detour is available.
- The detour route has an unacceptable LOS.

MDOT also has a list of conditions for applying a provision of special liquidated damages (SLD), which are disincentives with no incentive. The SLDs are similar to lane rental chargers in which the contractor pays a fee for the use of the road for the time it is closed, but there is no incentive paid to the contractor for an early completion. These SLDs include the following (Gillespie 1998):

The state would incur additional costs in the form of maintenance on temporary roads, or traffic control costs, even though user costs are not substantial.

Substantial user costs could be justified, but the construction time is too short to allow a meaningful incentive for early completion.

The amount of the SLD is substantive enough to cause the contractor to follow the schedule. This may not be enough by itself to justify the SLD in a court challenge.

The following policies and procedures for using incentives and disincentives were given as recommendations to VDOT (Gillespie 1998):

- Consider an I/D whenever the expected duration of a project is long enough to make early completion a valuable outcome.
- Consider the possibility of an A+B advertisement on every project for which an I/D clause is deemed appropriate.
- Judge the need for an I/D clause at the conclusion of the design public hearing.
- Decide whether to employ an I/D through an informed opinion of the contractor's behavior with and without an I/D.
- Decide the minimum incentive needed to encourage the contractor to complete the project.

An I/D should be considered only if an early completion is reasonably possible. If an early completion is not reasonable, then the incentive would be nearly useless and only a disincentive would be viable. Lane rental should be considered to encourage the completion of projects for short-term projects. The A+B method should be considered for all projects to encourage more innovative bids and ensure that the incentive will be

based on a more stringent timeline than the contractor has developed for the project. All data necessary to decide whether an I/D clause is needed, including traffic counts, forecasts, and preliminary road design and traffic maintenance plans, should be available at the end of the design public hearing. An I/D is only necessary to the point that it will encourage the contractor to complete the project as soon as possible. For example, an incentive of $5,000 should not be paid if $1,000 is sufficient. An informed opinion of the SHA concerning the contractor should be employed to determine how much of an incentive is needed to encourage the contractor to complete a project.

2.1.4 Applying User Costs

Once the decision has been made regarding when to apply a user cost, the SHA will need to decide how to apply that user cost to the project. This list from VDOT proposes some methods to implement a user cost for a project (Gillespie 1998):

- Base the I/D amounts on RUC savings derived from Highway Capacity Software (HCS).
- Base the I/D on the comparison between phases of the project.
- Calculate the user cost by separating various cost components, such as worth of time, VOCs (vehicle operating costs), and accident costs.

RUC savings may come from the HCS or any other software or method, but should be standardized throughout the SHA to ensure consistency. The I/Ds should be based on a comparison between phases of the project such as the capacity during the project to the capacity available once the project is complete. If a work zone is changed daily by closing lanes and reopening them, the comparison should occur between the

traffic flow during the hours that the lanes are closed and the likely traffic flow during those same hours of the day if the lanes were open. Using only one or two of the calculated user costs may be allowed if by so doing there is enough of an incentive for the contractor to hasten the completion of the project. Again, the SHA should only offer an incentive if the amount is sufficient to encourage the contractor to complete the project sooner than planned.

The RUCs themselves should also be considered while determining any of the following (Gillespie 1998):

- Calculating the benefit/cost ratio for a project or project element.
- Determining the preferred scheme.
- Determining the allowable lane closure schedule.
- Determining construction staging.
- Calculating the road user charge and lane occupancy charge.
- Determining the appropriate project delivery method.

An SHA should plan how to apply user costs into its projects. Certain information is required to estimate the total user costs by using equations, tables, or software. This includes knowing the following (New Jersey 2001):

- 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 speed limits.

- Work zone and normal capacity of the facility.
- Construction cost of alternative schemes.
- Construction costs of specific project elements.

Applying user costs to a project offers the contractor an incentive to expedite the project's completion, thus theoretically allowing traffic to flow smoothly with no disruptions. Incentives are not to be used as a method for the state to make money from a contractor. Gillespie (1998) explains this concept when he says that Virginia "will never lose a suit by using an I/D amount that is *smaller* than what the total user cost savings could justify."

2.1.5 Methods to Calculate User Costs

Although the focus of this chapter so far has been on the use of user costs and how to apply them, there are different ways to calculate the user costs. There are six general procedures to find user costs that were compiled by Ellis following a survey of transportation departments in the United States, Canada, Hong Kong, and the Virgin Islands (Ellis et al. 1997). These methods include the following:

- Simple formulas.
- Spreadsheets.
- High-level software.
- American Association of State Highway and Transportation Officials (AASHTO) "Redbook" method.
- Flat rates.
- No formal method.

Simple formulas are any calculations or combinations of formulas used to develop user costs. Spreadsheets include only those made by or especially for the SHA. This category does not include spreadsheets made by AASHTO or other generally available spreadsheets. High-level software indicates a software package available commercially. AASHTO Redbook method users include the formal Redbook procedures, as well as spreadsheets based upon the Redbook method. Flat rates are not based on calculations, but on legislation or other guidelines. There are still some states that have no formal method to calculate user cost values, nor do they use user costs for their projects.

Various equations have been created to facilitate determinations of user costs. Most are fairly similar in that they use an hourly value of time, value of mileage, VOCs, and other costs, although the equations may differ in how the value is actually determined. Hourly or per-mile values are combined with the time spent in the work zone, or the length of the work zone, and the number of vehicles affected to determine the total user cost.

2.1.5.1 Time Delays

According to Carr (2000), a work zone can produce three types of delay associated with time costs:

- Speed delay.
- Backup delay.
- Diversion delay.

The speed delay results from the slower speed through the work zone. The backup delay comes from the queue formed through the work zone. Diversion delay is not associated directly with traveling through the work zone, but is instead the delay associated with traveling on a detour route around the work zone.

2.1.5.2 Florida

Recommendations given to the Florida Department of Transportation state that the following three factors should be used when estimating the total user cost (Ellis et al. 1997):

- VOCs.
- Time costs.
- Accident costs.

The VOCs are those costs associated with the operation of the vehicle, which may include fuel, tires, maintenance, and other costs. The time costs are those costs dealing with the value of lost time. The accident costs are those costs incurred by accidents. Some states may not use accidents because of a paucity of data or difficulty in formulating the costs of accidents.

2.1.5.3 New Jersey

New Jersey has a list of various values and costs that may be used to the total user cost (New Jersey 2001):

1) Unrestricted Flow (Demand < Capacity):
    a) Speed Change with VOCs
    b) Speed Change Delay

c) Work Zone Delay

2) Forced Flow (Demand > Capacity):

a) Stopping VOC

b) Stopping Delay

c) Queue Delay

d) Queue Idling VOC

3) Circuitry:

a) Circuitry VOC

b) Circuitry Delay

4) Crashes:

a) Crash Costs

New Jersey uses only five of the previously listed delays and costs because they account for the greatest percentage of all costs (New Jersey 2001). These five costs are:

- Work zone delay.
- Queue delay.
- Queue idling VOC.
- Circuitry delay.
- Circuitry VOC.

The work zone delay is the value of the time lost by drivers traveling through a work zone that has a slower speed limit than the normal speed limit. The queue delay results from the worth of the lost time while drivers are stopped and waiting in the queue

itself. The queue idling VOC is the VOC due to idling for the length of time spent in the queue. The circuitry delay is the difference in time from the normal travel time and the time taken to travel along a detour or bypass route. The circuitry VOC is the difference in VOC of driving through a detour rather than the work zone or normal route.

2.1.5.4 Total Time Value

Equation 2-1 is used to determine the total value of the time lost at a work zone by calculating the product of the unit time value cost per time period and the time spent in the work zone (Herbsman et al. 1995).

$$TTV = UTV * T \tag{2-1}$$

where,

TTV = total time value ($),

UTV = unit time value ($/hour), and

T = time (hours).

2.1.5.5 Total Combined Bid

Equation 2-2, also from Herbsman, is a general equation for an A+B bid. The total is the sum of the construction cost and the total user cost for the duration of the product. The user cost is the product of the daily RUC and the duration of the project. A contractor can reduce the amount of his bid by reducing the duration of the project (Herbsman et al. 1995).

$$TCB = ECC + (DRUC * EPD) \tag{2-2}$$

where,

TCB = total combined bid ($),

ECC = estimated construction cost ($),

DRUC = daily RUC ($/days), and

EPD = estimated project duration (days).

2.1.5.6 Freeway Work Zone Cost Optimization

Another basic equation, shown as Equation 2-3, for determining the user cost of a work zone is one generated by Jiang and Adeli (2003). This equation is named the Freeway Work Zone Cost Optimization Model and sums the user delay cost, the accident cost, and the work zone maintenance cost. The work zone maintenance cost reflects the cost of setup and removal of the work zone combined with the cost of construction per mile or kilometer.

$$C_w = C_d + C_a + C_m \tag{2-3}$$

where,

C_w = freeway work zone cost ($/mile),

C_d = user delay cost ($/mile),

C_a = accident cost ($/mile), and

C_m = work zone maintenance cost ($/mile).

The user delay cost is calculated according to Equation 2-4.

$$C_d = \frac{c_{vh} t_d}{l * N_l} \tag{2-4}$$

where,

C_d = user delay cost ($),

c_{vh} = cost per vehicle hour ($/hour),

t_d = total user delay time (hours),

l = work zone length (miles), and

N_l = number of lanes closed in the work zone.

The accident cost is calculated according to Equation 2-5.

$$C_a = \frac{\alpha_n n_a c_a t_d}{10^8 l N_l} \quad \textbf{(2-5)}$$

where,

C_a = accident cost ($/mile),

α_n = darkness or working-at-night factor,

n_a = number of accidents per 100 million vehicle hours,

c_a = average cost per accident ($/accident), and

t_d = increased delay (hours).

The work zone maintenance cost is calculated according to Equation 2-6.

$$C_m = \frac{\alpha_n c_1}{l N_l} + \alpha_n c_2 \quad \textbf{(2-6)}$$

where,

C_m = work zone maintenance cost ($/mile),

c_1 = fixed cost independent of work zone segment length, and

c_2 = average additional maintenance cost per work zone per lane.

2.1.5.7 Work Zone User Costs

Another method of estimating the user cost in a work zone was created by Najafi and Soares (2001) and is summarized in Equation 2-7.

$$WZUC = TTDC + VOC + WZAC \tag{2-7}$$

where,

WZUC = work zone user costs ($),

TTDC = travel time delay costs ($),

VOC = additional VOCs ($), and

WZAC = work zone accident costs ($).

No specific method is given for finding the travel time delay costs except to use the Highway Capacity Manual (HCM) method or the Highway Economic Requirements System (HERS) software. Najafi and Soares (2001) advise that a value of $8 per hour should be used, regardless of the vehicle type. The VOCs are calculated using Equation 2-8.

$$VOC = ADC * V * D \tag{2-8}$$

where,

VOC = VOC ($),

ADC = average operating cost per unit distance ($/mile),

V = total number of vehicles, and

D = distance traveled (miles).

An annual average daily traffic (AADT) of less than 10,000 does not result in a significant delay cost, but when the AADT is greater than 40,000 the delay cost can be very significant (Martinelli et al. 1996).

The work zone accident costs are determined by multiplying the annual vehicle miles traveled (VMT) by crash rates per million vehicle miles, and by an estimate of cost per crash. For an urban interstate, the estimated cost per crash is as follows (Najafi et al. 2001):

- $6,000 per crash.
- $26,100 per injury.
- $2.5 million per fatality.

The relationship is as outlined in Equation 2-9.

$$WZAC = VMT * AR * CPAT \quad \textbf{(2-9)}$$

where,

WZAC = work zone accident costs ($),

VMT = vehicle miles traveled (miles),

AR = accident rate (accident/mile), and

CPAT = cost per accident type ($/accident).

2.1.5.8 Update to the 1977 AASHTO Redbook

An equation was presented in the *Development on an Update to the 1977 AASHTO Redbook* (2002) to formulate the change in user costs due to construction. This equation, summarized in Equation 2-10, is based on the value of time, VOCs, accident

costs, the volume of traffic before and after construction, and the length of the work zone (Development 2002).

$$UC_{k,c} = \left(\Delta H_{k,c} + \Delta OC_{k,c} + \Delta AC_{k,c}\right)\left(\frac{V_{k,c,0} + V_{k,c,1}}{2}\right)L \qquad \textbf{(2-10)}$$

where,

$UC_{k,c}$ = user cost (cents) for vehicle class c under contracting method k,

$\Delta H_{k,c}$ = change in value-of-time cost of construction delay (cents/vehicle mile) under method k,

$\Delta OC_{k,c}$ = change in VOCs (cents/vehicle mile),

$\Delta AC_{k,c}$ = change in accident costs (cents/vehicle mile),

$V_{k,c,0}$ = volume of vehicle class c before construction (Passenger Car Equivalent (PCE)/hour),

$V_{k,c,1}$ = volume (PCE/hour) of vehicle class c after construction, and

L = length of the construction zone (miles).

Equation 2-11 shows how to calculate the change in value-of-time cost of construction delay under method k.

$$\Delta H_{k,c} = 100 M_c O_c \left(\frac{1}{S_{1,k}} - \frac{1}{S_0}\right) \qquad \textbf{(2-11)}$$

where,

$\Delta H_{k,c}$ = change in value-of-time cost of construction delay (cents/vehicle mile) under method k,

M_c = value of time ($/hour) for class c,

O_c = vehicle occupancy for class c,

S_0 = speed before construction (miles/hour), and

$S_{1,k}$ = speed during construction (miles/hour).

The change in accident costs can be calculated according to Equation 2-12.

$$\Delta AC_{k,c} = v_I * \Delta I + v_D * \Delta D + v_P * \Delta P \quad \textbf{(2-12)}$$

where,

$\Delta AC_{k,c}$ = change in accident costs (cents/vehicle mile),

v_I = perceived cost associated with an injury accident (cents),

ΔI = change in expected number of injury accidents per vehicle mile,

v_D = perceived cost associated with a fatal accident (cents),

ΔD = change in expected number of fatal accidents per vehicle mile,

v_P = perceived cost associated with a property-damage accident (cents), and

ΔP = change in expected number of property-damage accidents per vehicle mile.

2.1.5.9 Summary of Finding User Costs

The costs associated with the various methods and equations recommended for use by the authors are summarized in Table 2-1.

Table 2-1: Methods for Determining User Costs

	Carr	Ellis et al.	New Jersey	Jiang and Adeli	Najafi and Soares	Update to Redbook
Delay Cost	**X**	**X**	**X**	**X**	**X**	**X**
Reduced Speed in the Work Zone	X		X			
Queue Above Capacity - Idling	X		X			
Detour			X			
Diversion	X					
VOC		**X**	**X**		**X**	**X**
Queue Idling			X			
Detour			X			
Accident Rate		**X**		**X**	**X**	**X**
Work Zone Maintenance				**X**		

(Carr 2000; Ellis et al. 1997; New Jersey 2001; Jiang and Adeli 2003; Najafi and Soares 2001; Development 2002)

All methods shown in the table use the delay cost of the work zone while the value of time must be known to determine the delay cost. Four of the six methods also use the VOC. More details of exactly how to find the VOC are presented later in this report. The table shows that four of the six methods use the accident rate.

2.1.5.10 Example of Lane Rental

Lane rental is charging a certain dollar amount to the contractor for closing a shoulder or lane of traffic at a certain time of the day. The cost for renting the lane is based upon the characteristics of the facility to be closed and the time of day for the closure. Some of the characteristics include the facility type, location of the facility, AADT, percentage of trucks, and time of day. Table 2-2 and Table 2-3 are two examples of how charges for lane rental can be organized.

Table 2-2: Example of Hourly Rental Charge

Lane Type	Daily Fees ($/day)	Hourly Fees 6:30 a.m. - 9:00 a.m. 3:00 p.m. - 6:00 p.m. ($/hour)	Hourly Fees All Other Hours of the Day ($/hour)
One Lane	20,000	2,000	500
One Shoulder	5,000	500	125
One Lane and Shoulder	25,500	2,500	625
Two Lanes	45,000	4,500	1,250
Two Lanes and Shoulder	50,000	5,000	1,375

(Sample 1991)

Table 2-3: Example of Daily Rental Charge per Half Mile

Two Lane Suburban Arterial Added Capacity ($/day per 0.5 mile)			
ADT	**0% Trucks**	**5% Trucks**	**10% Trucks**
2,500	400	400	400
5,000	800	800	800
7,500	1,200	1,200	1,300
10,000	1,600	1,700	1,700
12,500	2,100	2,100	2,100
15,000	2,500	2,600	2,600
17,500	3,000	3,100	3,100
20,000	3,500	3,600	3,700
22,500	4,200	4,300	4,300
25,000	4,900	5,000	5,100
27,500	5,800	5,900	6,000
30,000	6,900	7,000	7,200
32,500	8,200	8,300	8,500
35,000	9,500	9,700	9,800
37,500	10,800	11,100	11,300
40,000	12,400	12,600	12,800

(Daniels et al. 1999)

Although both tables are similar, there are some important differences between the two. Table 2-2, from the Federal Highway Administration (Sample 1991), specifies how many lanes and/or shoulders will be closed, with the rate charged based upon the time of day. Table 2-3, from Daniels et al. (1999), is an example of one of the numerous,

more detailed, tables that has been prepared for each type of facility. The table associated with the facility of interest is located, and the charge, based on the cost per day, is then chosen from the table based on the ADT and the percentage of trucks on the facility.

A rental charge may be determined using either of the table types presented in this section. Different rates of rental charge may be provided for a variety of possible divisions among ADT, percentage of trucks, or hours of closure. An SHA may want to provide tables with charges for each hour of the day, for fractions of an hour throughout the day, or one price for the whole day. Charges may be determined according to the facility type, ADT, percentage of trucks, or other characteristics. The complexity of the tables depends on the desires of the SHA.

2.1.6 Concluding Remarks

A plan should be prepared to accurately calculate user costs to apply them as incentives to contracts. The main methods for applying user costs are as I/Ds, cost and time or A+B, and lane rental. These can be applied whenever the SHA feels that such an incentive will be beneficial and useful to encourage a contractor to complete the work quickly. Incentives should be applied when substantial user costs will be realized. There are many ways to calculate user costs, and SHAs should determine which method will be best for their own situation.

2.2 Individual Costs

Once the general procedure for determining the user costs for a project has been defined, each specific value must be determined. This section reviews the individual

costs that may be used to determine the value of time, VOCs, and accident costs. Cost values may be from past years; therefore, calculations may need to be adjusted using the Consumer Price Index (Consumer 2005).

2.2.1 Value of Time

The value of time is important to determine the total user cost because time spent in a vehicle, especially in congestion, is time lost to the alternatives of being at home, work, or other places. Gillespie (1998) explains the value of time in the following manner:

> "Travel time cost is an opportunity cost—the difference between the value of the time that a vehicle's passengers spend en route and the value of the best alternative use of that time. The cost per hour of travel time depends on the opportunities for recreation or work that are available to passengers in the vehicle (the presence of cellular phones, car radios and even scenery will affect these possibilities) and on the opportunities available elsewhere. The travel time cost for cargo depends in a similar fashion on the inventory or carrying cost of the goods in transit, which depends on the relevant interest rate, and on the cargos' rate of deterioration or spoilage. A highway improvement normally expands capacity so that travel time is reduced."

The total value of time may be divided into various individual values as follows (Ellis et al. 1997):

- Factors affecting travel time values.
- Different categories of time values.
- Estimating the value of time.

Factors affecting travel time values include those that directly affect the amount of time traveling. Some of these factors may include characteristics of those traveling in the car, characteristics of the trip, geometric design of the highway, day of the week, time of day, activities that may be accomplished before and after the trip, or what may be done to utilize the lost time in the vehicle.

There are different categories of time, and each has its own value, meaning that one time of day may be more valuable than another time of day. These various categories may include working time, commuting time, leisure time, and commercial time. Entire days may also have different values associated with them, such as the difference between traveling on a weekday and traveling on a weekend. Weekday travelers are generally commuting to work or are traveling for work and, therefore, the time may be more important. On weekends, people are likely traveling for leisure or errands, and the time is valued less than that of weekday commuters.

Once the basic characteristics of the travelers and the trips are determined, estimating the value of time may be done by using chosen rates. The average base wage rate may be selected with other factors, such as a congestion factor or vehicle occupancy rate.

2.2.2 VOCs

The VOC should be found in order to determine the cost of traveling through a work zone with a car or truck. Table 2-4 shows operating costs from three different sources. The most common costs from all three sources are those associated with fuel, oil, and maintenance. Tire wear and depreciation are applied in two of the studies and can be considered as a VOC. Accident costs, though included in the report by Zaniewski et al. (1982), are considered as a separate cost apart from VOCs.

Table 2-4: Costs Used for Determining VOCs

Vehicle Operating Costs	Gillespie	Ellis et al.	Zaniewski et al.
Fuel	X	X	X
Oil	X	X	X
Maintenance	X	X	X
Tire Wear		X	X
Depreciation		X	X
Interest		X	
Accident Costs			X

(Gillespie 1998; Ellis et al. 1997; Zaniewski et al. 1982)

Truck operating costs are also determined with a similar list, but may include many more characteristics. Table 2-5 shows operating costs for trucks according to Zaniewski et al., the American Trucking Association (ATA) and the United States Department of Agriculture (USDA). The greater number of categories for truck costs is necessary because driving a truck constitutes employment, and there are, therefore, extra costs that are not generally associated with passenger cars.

Table 2-5: Costs Used for Determining Truck Operating Costs

Truck Operating Costs	Zaniewski et al.	ATA and the USDA
Fuel	X	X
Oil	X	
Maintenance	X	X
Tire Wear	X	X
Depreciation	X	X
Licenses		X
Driver Costs		X
Insurance		X
Interest on Tractor and Trailer		X
Management and Overhead		X
Interest on Other Items		X
Miscellaneous		X

(Zaniewski et al. 1982)

2.2.3 Accident Costs

Accidents may need to be considered in the total user cost, but there are some difficulties in using accident rates. Accident rates in the work zone may not be well-documented, and work zones can be fairly different from each other as some use concrete barriers and others use only cones and barrels. Furthermore, some accidents that occur within work zones may not be reported as having occurred in a work zone or as having been work zone related, therefore affecting the data available (New Jersey 2001).

If accident rates will be used in user cost estimation, an estimate of values relating to vehicular damage, injuries, and fatalities must be determined. Accident rates must also be determined using data collected by state agencies. Based on the accident rates and the values for damage, injuries, and death, the total accident cost may be determined and added into the total hourly rate for the user cost.

2.2.4 Concluding Remarks

An hourly rate of cost must be used to determine the total user cost. By multiplying the total lost time in a work zone with the hourly rates of the value of time, VOCs, and accident costs, the SHA will have a monetary value to use for incentives. To ensure that this value is accepted by all parties involved in a contract, the accuracy of these individual costs must be assured.

2.3 User Cost Values from Various States

Although each state may determine user cost values somewhat differently, the values eventually used are all somewhat close to each other. This section presents and compares values used by different SHAs.

2.3.1 Value Ranges

There are many methods that various SHAs employ to develop the user cost values, though most user cost values are similar to values from other states. Table 2-6 shows values used by individual states. All hourly rates have been adjusted to 2004 dollars using the CPI (Consumer 2005).

Table 2-6: User Cost Values from Other States

State	Automobile ($) (Adjusted to 2004)	Trucks ($) (Adjusted to 2004)
New Jersey[1]	14.51	24.18
Indiana[2]	16.42	45.29
Texas[3]	13.48	24.63
North Carolina[3]	9.80	-
New York[3]	10.13	23.80
Florida[3]	12.52	25.18
Georgia[3]	13.12	-
Virginia[3]	13.48	24.63
California[3]	13.63	33.78
Pennsylvania[3]	13.75	27.23
Washington[3]	14.09	56.30
Ohio[3]	14.19	29.73
California[4]	8.86	23.63
Colorado[4]	8.61	24.52
Illinois[4]	17.34	-
Nevada[4]	7.91	-
Washington[4]	13.37	66.86
Idaho[5]	13.63	33.00
South Dakota[6]	5.08	10.16
Minimum	5.08	10.16
Maximum	17.34	66.86
Average	12.31	31.53

(Calculated using data from New Jersey 2001[1]; Jiang 1999[2]; Daniels et al. 1999[3]; Ellis et al. 1997[4]; Idaho 2004[5]; South Dakota 1996[6])

From the literature search conducted in this study, user cost values range from $5.08 to $17.34 for automobiles and from $10.16 to $66.86 for trucks. The values shown in the table are adjusted from their published year to 2004 using the CPI. The average value is $12.31 for automobiles and $31.53 for trucks. In most states, the SHA has a reasonable basis for the value chosen, but a couple of values seem to be outliers. South Dakota, for example, uses a minimum wage value of $4.25, adjusted for this paper to

$5.04, for its value of time for automobiles and then doubles it for the truck value of time. These values seem to be fairly low. On the high end, Washington has a truck value of $50.00, adjusted for this paper to $66.86.

2.3.2 Values Used by States

The values shown in Table 2-6 are determined using a variety of methods, using certain costs that may or may not be used by other agencies. The following subsections describe how each of the agencies determines the value of time used. The original year uses the average for that year, while the value for 2004 has been adjusted using the CPI and the value given for the first half of the 2004 semiannual values.

2.3.2.1 New Jersey

The Time Value Cost Rate comes from NCHRP Report 133, which has a 1970 value of $3.00 per hour for automobiles and $5.00 per hour for trucks (New Jersey 2001). Values adjusted to 2004 are $14.51 per hour for automobiles and $24.18 per hour for trucks.

2.3.2.2 Indiana

The running cost for passenger cars is $78.49 per 1,000 vehicle miles at 60 mph in 1975 dollars. The running cost for combination trucks is $216.48 per 1,000 vehicle miles at 60 mph. These can be adjusted to $4.71 per hour for passenger cars and $12.99 per hour for trucks by dividing by 1,000 vehicle miles and multiplying by 60 mph (Jiang 1999). The values adjusted for 2004 are $16.42 per hour for automobiles and $45.29 per hour for trucks.

2.3.2.3 Texas

The value of time for automobiles is determined using the speed choice model developed by the Texas Transportation Institute (TTI). Truck value of time was based on values from a 1975 study by McFarland and Buffington reported by Daniels et al. (1999). The value of time was $11.97 per hour for automobiles and $21.87 per hour for trucks in Texas in the year 1999. Adjusted values to 2004 are $13.48 per hour for automobiles and $24.63 per hour for trucks. Texas also gathered values from North Carolina, New York, Florida, Georgia, Virginia, California, Pennsylvania, Washington, and Ohio. The values for each of these states were shown previously in Table 2-6.

2.3.2.4 Florida Department of Transportation

Ellis et al. (1997), working with the Florida Department of Transportation, conducted a study in which they gathered data on how various states calculated the value of time. The following are specific values of time that were given in the report with the actual values shown previously in Table 2-6.

California's value comes from data in a report from 1950 and was adjusted to the year 1995 using CPI data. Illinois includes a vehicle occupancy factor of 1.25 with its $10.00 value of time for automobiles. Nevada uses the value given in the AASHTO Redbook and adjusts it to the present-day dollars. The value of time Washington uses is one third of the average hourly wage according to the 1990 census data, and VOCs are added in for the total hourly value of time.

2.3.2.5 Idaho

Idaho uses a document to guide the engineer or manager in the determination of the total user cost to apply to projects. The value of time is listed as $11.40 per hour for

automobiles and $27.60 per hour for trucks. There is no explanation of how these values were determined. Adjusting to 2004 dollars, these values are $13.63 per hour for automobiles and $33.00 per hour for trucks as indicated previously in Table 2-6 (Idaho 2004).

2.3.2.6 South Dakota

South Dakota simply uses the minimum wage for the state as the value of time for automobiles, which was $4.25 per hour in 1996. The value for trucks is twice the amount of minimum wage, or $8.50 per hour. Simply adjusting these values by the CPI to 2004 dollars, the values are $5.08 per hour for automobiles and $10.16 per hour for trucks as indicated previously in Table 2-6 (Criteria 1996).

2.3.2.7 Discrepencies

There appear to be some discrepancies in these data, such as two different values for the states of California and Washington. These values are presented in the report separately because they are somewhat different and signify that values may change, although there is no indication of why they are different between the two reports.

2.3.3 Concluding Remarks

Many states reported in this section have a user cost value of $12 to $13 per hour for automobiles and the mid-$20 per hour range for trucks. The values are generally related to the job wage in the state or are based upon the AASHTO Redbook values.

2.4 Discretion

Although a state may use a prescribed method to determine user costs, every project is different, and the engineer will need to make a decision adapted to the specific circumstances of that project. The user cost values provided for the project may be too large for various reasons. The engineer should have basic guidelines to follow for adjusting the user cost values to their satisfaction.

2.4.1 Reasons for Adjustments

The last step from Daniel's plan for determining the RUC was to determine the adjustments needed. Adjustments may be based upon the following (Daniels et al. 1999):

- Importance of on-time completion.
- Current contracting capacity and pool of projects available.
- Reasonableness of calculated excess RUC.
- Complexity of project and extent of "unknowns."

Adjustments may or may not need to be made based upon the importance of completing a project on time, the location of the project, the classification of the facility, or traffic volumes. Some projects may need to be finished as quickly as possible, while other projects that do not markedly affect traffic flow may not need to be completed as urgently.

If contractors have already extended their equipment and resources over many projects, a user cost charge that is too high may result in few or no bids for the project. Contractors may be more cautious of possible penalties due to a lack of resources and manpower and may possibly not bid for the project.

The method used to calculate the user cost may result in a charge that is higher than that needed to entice contractors. Therefore, the engineer should reduce the calculated amount to a charge that is beneficial to both the SHA and the contractor.

The user cost charge may need to be adjusted according to the complexity or unknowns of the project. Unknown problems related to a project may include geological problems, weather, or even archeological findings encountered during the project. Any unknowns may cause delays in the completion time and the contractor will not want to be charged for delays over which he had no control.

2.4.2 Other Considerations

Herbsman and Glagola (1998) discuss a study from the Colorado Department of Transportation that mentions several questions to consider while using lane rental. Although these may not be directly related to the discretionary adjustment of user costs, they are important for deciding when and how the contractor can work, which will affect how the user cost charges should be employed. The items to consider are as follows (Herbsman and Glacola 1998):

- Are all work items clearly defined and shown on the plans at the time the contractor bids on the project, including when the lane rental time will start and when it will be stopped?
- Are there other preferred alternatives for traffic maintenance to consider?
- Should night work be mandatory, allowable, or disallowed?
- Should weekend work be mandatory, allowable, or disallowed?
- What impacts will night work have on residents in the area (e.g., noise)?
- Are all utilities and other possible conflicts shown clearly on the plans?

- Are all traffic control plans at intersections within the lane defined?
- Are additional personnel needed during this operation?
- Can the quality of certain items be relaxed and, therefore, be considered for scheduling for completion as night work?
- Remembering that safety to the traveling public should have precedence over getting the work completed, at what point should weather be a factor, and who is empowered to authorize suspension of the work?

A timeline or schedule detailing when work is allowed will affect the discretionary charge of user costs. Although an SHA may desire that a project be completed within a certain amount of time, if work is not allowed during certain hours of the day, then there may be little the contractor can do to complete a project much earlier.

Any unidentified utilities or other unknowns may jeopardize the project's timeline. Therefore, all known utilities and other possible conflicts should be shown on the plans to allow the contractor to take measures to avoid problems and delays.

The contractor should provide enough employees for the project. The SHA should also ensure that transportation engineers and inspectors are readily available for inspections and to answer questions when they arise. Providing this support will allow the contractor to continue working with minimal delays.

The SHA must decide whether a lower quality of materials may be used due to night work if some materials are not available during the night. The SHA may still retain any material quality requirements, but doing so may cost more and may affect the amount of time required to complete a project.

Inclement weather may cause unsuitable conditions for construction and maintenance projects and may affect the project's timeline. The contract should specify who makes the decisions about how penalties will be adjusted due to the forces of nature. Still, this may be adjusted by the engineer as a discretionary decision.

2.4.3 Concluding Remarks

Applying user costs to a project involves preparation and planning to ensure the validity and reasonableness of costs and values. At times, the values calculated do not correctly reflect the level of importance of the project or may be so high that they discourage contractors from bidding on projects. The engineer's discretion must be used and trusted to adjust the predetermined values and apply them to specific projects.

2.5 Summary

As outlined in this chapter, there are a variety of ways to calculate user costs and to subsequently apply those user costs as incentives to projects where the benefit would be most advantageous. There are three main divisions or portions of a total user cost value used, which are the value of time, VOCs, and accident costs. Many states mentioned in this report use values in the $12 to $13 per hour range for automobiles and mid-$20 range per hour for trucks. User costs should be calculated in a manner that is reasonable and that ends with a sound and rational value.

Chapter 3. Survey of SHAs

A questionnaire survey was sent to all SHAs in the United States to inquire about how they determine user costs. Thirteen questionnaires were returned from the states of Arizona, Arkansas, Idaho, Kansas, Louisiana, Maryland, Michigan, Minnesota, New York, Rhode Island, South Dakota, Texas, and Wisconsin. The purpose of the questions was to determine whether incentives have produced positive results, the type of incentives states use, which costs or values the states utilize to determine the user costs, and how adjustments to the values are applied to contracts. A copy of the SHA questionnaire is provided in Appendix A.

3.1 Use of User Costs

Most SHAs that replied apply user costs, though a few states do not. Of those states that do apply user costs as some sort of incentive or disincentive, only one has encountered difficulties with contractors resisting the amount penalized against them. Ten of the 13 states have facilitated faster completion times by using incentives. Table 3-1 provides a summary of how each state applies user cost values to projects.

Table 3-1: Methods for Applying User Costs

	Arizona	Arkansas	Idaho	Kansas	Louisiana	Maryland	Michigan	Minnesota	New York	Rhode Island	South Dakota	Texas	Wisconsin	**Total States**
Incentive/Disincentive (I/D)	X	X	X	X	X		X	X	X		X	X	X	11
Disincentive Only	X			X	X			X	X			X	X	7
Cost/Time (A+B)	X				X		X	X			X	X	X	7
Cost/Time with I/D	X	X	X		X			X	X		X	X		8
Lane Rental	X	X	X		X		X	X	X		X	X	X	10
No Method														0

3.2 Determining User Costs

The majority of those states that responded utilize user costs for most types of incentives. These incentives include simple I/Ds, A+B, A+B with incentives, and lane rental. Although most states do employ user costs for incentives, there are various methods for calculating the user costs. A summary of the types of methodologies utilized is provided in Table 3-2. Table 3-3 displays the costs and values used to determine the user costs.

Table 3-2: How User Costs are Determined

	Arizona	Arkansas	Idaho	Kansas	Louisiana	Maryland	Michigan	Minnesota	New York	Rhode Island	South Dakota	Texas	Wisconsin	**Total States**
Simple Formulas	X		X	X		X					X	X	X	7
Spreadsheets	X					X	X	X	X		X	X		7
High-Level Software													X	1
AASHTO Red Book		X							X					2
Flat Rates														0
No Formal Method												X		1

Table 3-3: What to Use to Determine User Costs

	Arizona	Arkansas	Idaho	Kansas	Louisiana	Maryland	Michigan	Minnesota	New York	Rhode Island	South Dakota	Texas	Wisconsin	**Total States**
Delay Cost	X	X	X			X	X	X	X		X	X	X	10
VOC		X					X	X	X		X		X	6
Accident Costs		X				X			X		X		X	5
Environmental Impacts														0
Social Impacts	X													1
Legislation or Policy														0
Not Applicable														0

Seven of the 13 states use hand calculations or simple spreadsheets to calculate the user costs. Two states use the AASHTO Red Book Method, and very few use some sort of high-level software.

There are many costs that are used in the calculations, including delay costs, VOCs, accident costs, environmental impact costs, and social impact costs. There are various ways of determining the values for each of these costs that will be discussed in the following sections.

3.2.1 Delay Costs

Delay costs can be categorized into three sections: the value of time, the lost time, and how to determine the lost time on a detour. The delay cost is determined by multiplying the value of time by the amount of time lost due to the construction or detour. Table 3-4, based on the survey results, provides a summary of methodologies used to determine delay costs.

Table 3-4: How to Determine Delay Costs

	Arizona	Arkansas	Idaho	Kansas	Louisiana	Maryland	Michigan	Minnesota	New York	Rhode Island	South Dakota	Texas	Wisconsin	**Total States**
Value of Time														
Not Applicable				X	X					X		X		4
Average Wage	X								X		X		X	4
Reason for Travel						X								1
Complete Tasks During Commute														0
Persons per Vehicle						X		X	X					3
Extra Tasks to be Completed														0
Day of Week	X												X	2
Time of Day	X					X			X				X	4
Lost Time in the Work Zone														
Deceleration								X			X			2
Reduced Speed	X	X	X			X		X			X		X	7
Acceleration								X			X			2
Below Capacity Queue								X						1
Above Capacity Queue	X	X				X		X					X	5
Determine Lost Time on Detour														
Hand/Local Knowledge	X	X				X	X	X	X		X		X	8
Software							X				X		X	3

The value of time may be found by focusing on a variety of topics, including average wage, reason for travel, persons per vehicle, time of day, day of the week, ability to complete tasks while traveling, and the importance of completing other tasks. Four states use average wage, and four states use time of day for calculations. Four of the highway agencies surveyed do not use the value of time for their calculations, and three of the states use a vehicle occupation factor to adjust the value of time. Two of the states use data about the specific day of the week or the reason for travel. None of the states that responded indicated using data corresponding to the ability to complete tasks while traveling or what may need to be done after work.

Lost time caused by work zone delays may be due to deceleration required of drivers approaching the work zone, reduced speed in the work zone, time spent accelerating back to the normal free-flow speed after the work zone, the queue caused by a demand above the capacity, and the detour or alternate route. Eight of the 13 states use lost time associated with detour or alternate routes, while seven of the states use the lost time associated with reduced speed through the work zone. Four of the states use the lost time caused by the queue. Two states use the lost time caused by deceleration to and acceleration from a work zone. Therefore, if there is no detour route, the most commonly used factors affecting lost time calculations are the delay or reduced speed while traveling through the work zone and the delay caused by the queue.

When a detour is planned in conjunction with a work zone, there are two primary ways to determine the amount of lost time caused by the detour route. The lost time may be determined manually, allowing the engineer to use his or her own knowledge of the

local area, or the lost time may be determined using computer software. Eight states simply use local knowledge of the area to determine the lost time, although four states do use software packages to calculate lost time.

3.2.2 Vehicle Operating Costs

User costs may also include costs associated with vehicle operation. These values may include the costs of fuel, oil, maintenance, tire wear, insurance, license, depreciation, and interest. Table 3-5 displays the VOCs used by each state as determined in the survey.

Table 3-5: How to Determine VOCs

	Arizona	Arkansas	Idaho	Kansas	Louisiana	Maryland	Michigan	Minnesota	New York	Rhode Island	South Dakota	Texas	Wisconsin	**Total States**
Not Applicable	X				X	X				X		X		5
Fuel								X	X		X		X	4
Oil								X	X		X		X	4
Maintenance								X	X		X		X	4
Tire Wear								X	X		X			3
Insurance											X		X	2
License											X			1
Depreciation									X		X		X	3
Interest											X			1

Five states do not use any VOCs. Of those states that use VOCs, four use values for fuel, oil, and maintenance. Four of the 13 states use costs from tire wear or depreciation. Other costs are used by very few SHAs.

3.2.3 Accident Costs

The costs incurred by accidents can be fairly high. The accident rate to be used should be the difference between the normal situation and the rate of accidents within a

work zone. Table 3-6 displays those states that use accident costs according to the survey results.

Table 3-6: How to Determine Accident Costs

	Arizona	Arkansas	Idaho	Kansas	Louisiana	Maryland	Michigan	Minnesota	New York	Rhode Island	South Dakota	Texas	Wisconsin	**Total States**
Not Applicable	X		X	X	X		X	X		X		X	X	9
Total Accident Rate						X			X		X			3
Accident Rate in Work Zones						X			X					2
Cost of Damage									X		X			2
Cost of Injury											X			1
Cost of Death											X			1

Nine of the 13 states do not use accident costs. Only three of the states use the total accident rates, and two states use the accident rates within work zones. One state, South Dakota, uses all three accident costs of damage to vehicles, injuries, and death.

3.2.4 Environmental Impact Costs

Environmental impact costs are those that deal with the impact of increased air pollution caused by more fuel consumed due to slower speeds and delays in the work zone. Environmental impact costs are not used by any of the states that returned the questionnaire.

3.2.5 Social Impact Costs

Social impact costs are those costs incurred upon businesses in the area impacted by construction. Only one state, Arizona, considers the costs due to lost business.

3.2.6 Concluding Remarks

According to the replies from responding states, user costs are determined using similar methods and values. Several states use simple methods or spreadsheets to calculate user costs. Most states use delay costs caused by reduced speed through the work zone and quantify the value of that time using the average wage. Usually those states that use VOCs base the value upon fuel, oil, and maintenance.

3.3 Adjustments

Once a value for user costs is calculated, some downward adjustment may be needed if the engineer determines that is best. Table 3-7 shows how the states adjust values as needed.

Table 3-7: How to Adjust User Cost Values

	Arizona	Arkansas	Idaho	Kansas	Louisiana	Maryland	Michigan	Minnesota	New York	Rhode Island	South Dakota	Texas	Wisconsin	**Total States**
No Adjustments Made				X	X	X				X				4
Predetermined Min and Max	X		X						X		X	X		5
Predetermined Percentage												X	X	2
Engineer's Discretion		X					X	X			X	X	X	6

Five of the reported states have a predetermined minimum or maximum amount that is allowed for adjusting the user cost values. Six of the states allow the engineer to use discretion in making the decision of how to adjust the user cost values if needed. Four of the states make no adjustments to the value determined for user costs.

3.4 Summary

Based upon the data collected from the 13 states that responded to the questionnaire, Table 3-8 displays the highest given answer from each section to determine user costs.

As displayed in Table 3-8, simple formulas and spreadsheets are the most popular methods used to determine user costs. Ten states use the delay cost to determine user costs, but only six of the states consider VOCs.

In determining the value of time, four states use the average wage, while another four states use the time of day. Seven states use the reduced speed to determine the lost time in a work zone. To determine the lost time caused by detour routes, eight states use simple hand calculations or local knowledge to determine those costs, instead of using software.

The majority of the states that responded do not use the vehicle operating, accident, environmental, or social costs. Five states do not use VOCs. Nine states do not use accident costs. None of the 13 states who responded to this survey use environmental impact costs, and only one state uses social impact costs. To adjust the determined user cost values, six states allow the engineer to use his discretion to adjust the values as needed.

The results which were collected in this research show a general consistency for determining user costs among the different states which responded. These results were compared to the plan created for UDOT to determine its own user cost values for Utah projects.

Table 3-8: Compilation of Most-Used Methods and Values

	Arizona	Arkansas	Idaho	Kansas	Louisiana	Maryland	Michigan	Minnesota	New York	Rhode Island	South Dakota	Texas	Wisconsin	**Total States**
How to Determine User Costs														
Simple Formulas	X		X	X		X					X	X	X	7
Spreadsheets	X					X	X	X	X		X	X		7
What to Use to Determine User Costs														
Delay Cost	X	X	X			X	X	X	X		X	X	X	10
How to Determine Delay Costs														
Value of Time														
Not Applicable				X	X					X		X		4
Average Wage	X								X		X		X	4
Time of Day	X					X			X				X	4
Lost Time in the Work Zone														
Reduced Speed	X	X	X			X		X			X		X	7
Determine Lost Time on Detour														
Hand/Local Knowledge	X	X				X	X	X	X		X		X	8
How to Determine VOCs														
Not Applicable	X				X	X				X		X		5
How to Determine Accident Cost														
Not Applicable	X		X	X	X		X	X		X		X	X	9
How to Determine Environmental Impacts														
Not Applicable	X	X	X	X	X	X	X	X	X	X	X	X	X	13
How to Determine Social Impacts														
Not Applicable		X	X	X	X	X	X	X	X	X	X	X	X	12
How to Adjust Determined User Cost														
Engineer's Discretion		X					X	X			X	X	X	6

Chapter 4. Interviews with UDOT Personnel

UDOT employees were questioned to better understand what they would prefer in a comprehensive plan used throughout UDOT for determining user cost values. Those employees who will use the program were invited to participate in the interviews, and four UDOT employees agreed to meet for questioning. Two employees were from the UDOT main office in Salt Lake City and two were from the Region 3 office in Orem. A summary of the UDOT personnel questionnaire is provided in Appendix B.

4.1 How to Determine User Costs

According to those surveyed, the actual method to determine the user costs was not as important as was the ease of use associated with the method. UDOT engineers do not have much time to learn difficult, new software or methods, and therefore do not want to be disenfranchised by a method to determine user costs that is not easy to use. Quick and simple are the key goals for this method.

Questions asked of the UDOT employees were similar to those found on the questionnaire sent to SHAs. Of the various costs that may be used to determine the user costs, the three costs that employees of UDOT would like to use are delay costs, VOCs, and accident costs. The UDOT personnel showed very little desire to use environmental

and social costs to determine the total user costs. Furthermore, to avoid excessive complication, they did not feel that adjustments should be made to the costs based upon location within the state, as this would complicate the process.

4.1.1 Delay Costs

Delay costs should be determined using the amount and value of lost time resulting from delays in a work zone. Lost time should be based on speed reduction caused by the work zone, time lost in queues, and time lost on detour routes. The value of time should be based on the average wage in the state of Utah. The average vehicle occupancy should also be used to adjust the value of time cost because more than one person per vehicle would be affected.

4.1.2 Vehicle Operating Costs

The cost of fuel is the major factor that should be used for the VOCs. There was no clear majority among the UDOT employees interviewed in this research supporting other possible operating costs.

4.1.3 Accident Costs

All four of the UDOT employees questioned thought that accident costs should be used in determining the total user cost calculation. Unfortunately, there was no clear consensus regarding how to actually determine the accident costs.

4.1.4 Other Factors

Other than the previously mentioned specific costs, there are other factors that must be taken into consideration when determining user costs. The employees questioned agreed that the following should also be used for calculating user costs:

- AADT.
- Length of work zone.
- Number of lanes closed.
- Day of week.
- Time of day.
- Percentage of cars and trucks.
- Functional class of the facility.

Although “functional class” was mentioned by only one person, a strong case was made for using it. This factor can greatly affect the total costs incurred in a work zone because the capacity on a freeway is much higher than the capacity on an arterial.

4.1.5 Concluding Remarks

According to those UDOT employees interviewed, user costs should be based upon lost time caused by delay in the work zone, queuing, and detour routes; and the value of that lost time should be based upon the average wage in Utah. VOCs should be based only upon fuel costs, and accident costs should ultimately be used; however, using accident costs is not feasible at the present time. There are many other factors that should also be used in determining user costs, based upon characteristics of the facility and work zone.

4.2 Adjustments to Cost

Calculated user cost values may be higher than the values needed by UDOT. The point was reiterated by various employees that UDOT wants a value high enough to

encourage the contractor to finish the work as soon as possible, but not too high that it may cause extreme negative consequences to the contractor if some unforeseen event occurs. UDOT does not want to make money off of contractors who may be somewhat behind in project schedules, but only encourage them to work quickly. UDOT also hopes that incentives, like lane rental, will encourage contractors not to work during the peak hours. Of course, some locations, like major freeways, may not allow work during peak hours. Neither UDOT nor contractors should interpret that applying user costs to a project implies constant policing by a UDOT employee watching for any small infraction. Instead, the application of user costs concept to project management is meant to encourage habitually delayed contractors to stay on schedule.

Because of individual site delays that may occur during the construction process, final adjustments should be made by the resident engineer on the project who should be the one to make a decision as to whether a disincentive should be placed upon the contractor. Because a contractor may contest a disincentive, UDOT should be able to adjust the amount charged as needed. At the same time, UDOT should begin a project with a value that is reasonable and justifiable in court.

UDOT may adjust user cost values simply by being familiar with the size and scope of the project, the location of the project, and the work ethic of the contractor. The engineer should provide an estimate of the time frame needed to complete the work. The engineer's estimate should provide a basis or idea for the amount of time that the contractor should need for the project. Planned times, adjustments, and incentives should be based upon the engineer's and contractor's estimated completion date. The UDOT

personnel interviewed agree that no incentive amount should be greater than about 10 to 15 percent of the total contract.

4.3 Additional Insights

The method used to determine the user costs should be easy to use and include easy-to-read tables or other estimation mechanisms. Computer software can be expensive, difficult to learn, and may have to be updated regularly; therefore, complex software should be avoided or only used on large projects, though software does not have to be excluded from use altogether. Simple methods should be used for hourly, daily, or weekly closures. The total time needed to determine the user costs should be very small, certainly less than one day.

An issue was raised concerning quantification of the costs incurred when cars leave the work zone and travel on a bypass route. This issue can be addressed by assuming that all traffic on a facility stays on that facility, even though in reality some may leave to travel on a different route. By traveling on a detour, drivers may experience a new set of delays due to slower speed limits, traffic signals, congestion, and greater travel distances. Attempts to estimate the number or percentage of vehicles leaving a work zone for a bypass would take time and may require running a demand forecasting program that may not be appropriate for small projects.

Drivers are willing to be delayed in a work zone if they can observe work being accomplished and are more frustrated in a situation where lanes are closed, or there is a reduced speed limit, and they see no work underway. UDOT hopes that using incentives

based upon the user costs will encourage contractors to continually work and not have days or weeks during which no work is occurring within the work zone.

4.4 Summary

The information gathered during the interviews provided useful ideas that should be implemented into a department-wide system UDOT can use for the calculation of user costs. The following are the key suggestions:

- Any system should be simple and easy to use.
- Delay costs should be based upon the speed reduction while in the work zone, time lost in a queue, and time lost on a detour.
- VOCs should be based upon the cost of fuel.
- Accident costs should theoretically be used, but no consensus has been made with regard to how to determine the costs.
- Other factors for cost calculation should include AADT, work zone length, number of closed lanes, day of the week, time of day, percentage of cars and trucks, and functional class of the facility where the construction occurs.

Adjustments to the value used as an incentive should be made to encourage the contractor to complete the project in a timely manner. The value should be one that UDOT is willing to pay and that is high enough to encourage the contractor, but it should not constitute overpayment.

Computer software, if used, should be simple to understand and use. Also, all vehicles should be assumed to stay on the facility through the work zone when the

facility is partially closed because of the complexity involved with estimating the number of drivers that may divert to a bypass route.

Chapter 5. Computer Software

Computer software can greatly assist in the work necessary to determine user cost values. Determining costs can involve numerous calculations, and software is able to perform many of these calculations in a quicker time frame than manual calculations could be accomplished. Four computer programs are introduced here, including discussions of strengths, weaknesses, and possible applications for UDOT.

5.1 MicroBENCOST

MicroBENCOST was created by TTI in the early 1990s. The version studied for this research was DOS-based. MicroBENCOST is designed to assist in making decisions about whether to build a new facility, improve a facility, or do nothing. To address a decision concerning what to do with a facility, MicroBENCOST employs user cost values but only considers the long-term effects and costs. The user costs needed for the decision about the type of improvement are based upon the level of service over the study period, the facility that would be best for minimizing travel time or user costs is recommended. This program does not consider short-term conditions, such as immediately before, after, or during a work zone closure, but only the long-term conditions over many years. The program does take into consideration construction

costs, but only as a part of the overall cost on the facility over the study period. The cost of construction may be just one of the factors that may increase the user costs associated with the facility over a 20-year study period, for example. Regardless of whether the study period is 20 years of just one or two years in length, the purpose of MicroBENCOST is to determine which facility to build. The purpose of MicroBENCOST is not to determine the user costs within a work zone for a relatively short amount of time, but to determine the user costs on a facility over many years (MicroBENCOST 1993).

MicroBENCOST has many inputs, is DOS-based, and is difficult to work with because there is no visual diagram or layout of the system on the monitor. Numerous screens and menus are available for adjusting nearly every value. There is more detail in this program than what is wanted or needed by UDOT. Also, because this program is not easy to use, it is probably not well suited for use by UDOT.

5.2 QuickZone

QuickZone is a Microsoft Excel-based program developed by the Federal Highway Administration (FHWA) in the late 1990s and released in late 2001. QuickZone is designed for larger projects involving lane closures over an extended period of time and detours for the work zone. The program, though, may be used for short-term projects of only a couple of days or even several hours (QuickZone 2002).

QuickZone may be a good program for UDOT to use; however, some troubles were encountered in using the program. Although there are instructions on how to enter in data, there is little documentation on how to interpret the results. Although the

network is displayed on the screen, no node or link numbers are shown. Without a network to see, users cannot really determine the numbering of links and nodes if corrections need to be made. Overall, several roadblocks were encountered in this research when using the program due to lack of detail in the instruction manual.

Once the majority of the confusion was resolved, a simple network similar to a work zone analyzed by a UDOT employee was entered into the program for evaluation in this research. This scenario was based on a freeway section being closed for a weekend and all traffic being diverted onto surface streets. The UDOT engineer's estimate was nearly $9,000 for one scenario and nearly $90,000 for another similar scenario. QuickZone gave an answer of $0 for the user costs in both cases, an obviously unacceptable value. Other scenarios were created and also returned unreasonable values.

QuickZone may be a very useful program once the user interfaces and output results are improved and easier to understand. There are many states that already use the software. Unfortunately, the experience obtained in this study suggests that QuickZone would not be appropriate for UDOT use at this time due to its lack of ease of use.

5.3 Delay Enhanced (DelayE)

Delay Enhanced (DelayE) is Windows-based software created by Martin Knopp in the late 1990s while at UDOT and is based on a deterministic queuing analysis. The purpose of this software is to determine the user cost due to queuing on the freeway. Whether this is due to an evening rush or a work zone does not matter. The program is easy to use, incorporating a simple, visually-based interface. The number of lanes is displayed along with an "X" over the closed lanes and shoulders, which is intuitive for

first-time users. Using the normal number of lanes and the number of closed lanes, DelayE calculates the capacity for the highway at that location. The user then enters the demand for consecutive time periods and may then determine what the delay will be and the amount of the cost incurred (Delay 2000)

DelayE assumes that traffic is flowing without problems until the demand is greater than the capacity. The program can only be run if the first time frame contains demand greater than the capacity, at which point the program determines how much of a queue has formed. Subsequent time periods may be added after the first, but the demand is allowed to be less than the capacity in these. DelayE determines how long the queue will take to dissipate and, in the process, determines the user costs for driving on that facility. The length of the queue, total lost time, and total user costs are calculated.

DelayE is ideal for determining work zone delays where no detour or bypass routes are available, such as freeways. DelayE is good when queues are expected, but is not useful for finding the cost due to delays caused by a reduction in speed.

5.4 DUCK

DUCK stands for Delay User Costs and is a simple Excel spreadsheet designed to determine the user costs associated with a simple delay due to reduced speeds in work zones. DUCK was created by the author following a simple method used by Michael Kaczorowski of UDOT; it was expanded, however, to assist in the management and automation of data relating to traffic volumes. The goal of UDOT is to have a simple, easy-to-use system of determining user costs, and DUCK was created for UDOT to achieve that goal.

DUCK only computes the total lost time due to reductions in speed experienced by drivers traveling on freeways or detours; it does not calculate queue delays like DelayE. This program is fairly simple and the calculations are not difficult. The benefit of DUCK is that it has been designed to assist in the calculations of user costs by gathering data concerning traffic counts for each hour of the day on arterials and freeways, and on weekdays and weekends.

To begin an analysis using DUCK, the user enters the range for the day and time of the closure, the AADT, the number of lanes normally open, the number of lanes that are closed, the length of roadway closed, and the speed limits on the route. Detour route information needs to be entered only if a freeway will be completely closed and all traffic will be moved to surface streets. The actual calculations are performed on a variety of other worksheets. For example, the user enters the AADT, and the program calculates the number of vehicles for each hour of every day and displays the total number of cars and trucks traversing the facility during the work zone closure. The program then uses the value of time and VOCs per hour for cars and trucks to compute the total user cost. A full simulation can be entered in and finalized in only a few minutes, with one worksheet formatted for printing a summary of all results on one page.

5.5 Summary

Of the computer software and programs discussed, the recommendation to UDOT is to use DUCK and DelayE, in this order. Both are easy to use and require little time to learn. The final user cost value in DUCK reflects variables requested by employees at UDOT, including AADT, work zone length, number of closed lanes, day and time of the

closure, percentage of cars and trucks, and the functional class of the facility where the construction occurs. Hourly and daily volumes are computed, which may be used as inputs needed in DelayE. Although not integrated into one program, DUCK and DelayE should be used together for computation of user costs by UDOT.

Chapter 6. Procedure for UDOT

Using the gathered information, a procedure is set forth for UDOT to follow to apply user costs in a simple, defendable, and consistent manner throughout the department at each of the regional offices. This section presents a flow chart describing how to calculate and apply those user costs, what UDOT must decide to use for certain cost values, and when to apply user costs to highway project contracts.

6.1 Decisions for UDOT

UDOT should ensure that the value of time and the VOCs used correctly reflect the estimated values. UDOT should also ensure that the average percentages of cars and trucks in Utah are accurate for use in the user cost calculations. Values already integrated into the DUCK program should be reviewed for acceptability. The values can be adjusted as needed, but default values already used in the program are justifiable and are based upon the results of the literature search presented earlier.

6.1.1 Value of Time

The value of time is multiplied by the lost time to determine the total cost due to reduced speed delay. Therefore, this value may be the most controversial of the user cost

estimation procedure. UDOT desires to have a value that is both justifiable and reasonable and that can be upheld in court if ever disputed.

According to the U.S. Department of Labor, Bureau of Labor Statistics, November 2003 State Occupational Employment and Wage Estimates for Utah, the average wage for employees in the state of Utah is $16.15 per hour. The average wage for truck drivers is slightly more at $17.55 per hour (Occupational 2003). These values may be used as a basis for the value of time. As shown previously in Table 2-6, the average values for automobiles and trucks, according to the gathered data, are $12.31 and $31.53, respectively. Often, 50% of the average wage is used as a representative value of time in economic analyses; however, it depends on many factors. However, it is not a practice to use the full value (100%) of the average wage. A value between 50% and 75% appears to be reasonable.

6.1.2 Vehicle Operating Costs

The decision has been made to only use fuel costs for the VOCs because fuel can be the main cost of operating a vehicle (see Section 4.1.2), and idling in traffic consumes fuel. Although other states may use additional costs, such as those for tire wear, maintenance, or even insurance, these costs are often so small per hour that they may not be worth the effort required to integrate them into the system. Besides the complexity of finding those other values, keeping only the cost of fuel, which can be fairly easy to determine, means that the VOC will be easier to justify.

Values for the cost of fuel and the average vehicle fuel efficiency are available from the U.S. Department of Energy. The department website shows that in May 2005

for the Rocky Mountain region, the average gasoline price was $2.23 per gallon, and the average diesel price was $2.27 per gallon (Gasoline 2005).

6.1.3 Percentage of Cars and Trucks

One other decision that UDOT needs to make concerns the percentages of cars and trucks in the total vehicle traffic. These values can greatly affect the total outcome because the value of time is higher for trucks than for automobiles. That is, as UDOT uses a greater percentage of trucks, the total user cost will increase. The assumed truck and automobile percentages should represent the vehicle mix actually on the highways. Truck traffic data are available from the Planning Division of UDOT or viewable on UDOT's website and a truck traffic report can be downloaded from the Internet.

6.1.4 Consistency

Another issue that must be addressed is ensuring that the same values for individual costs, such as values for time and fuel cost, are used throughout the various computer programs and throughout UDOT. The values in DUCK can be changed easily, as can the values in DelayE. This issue affects the value of time, VOC or fuel cost, and the percentages of cars and trucks.

6.1.5 Concluding Remarks

UDOT must ensure that the values used in its user cost calculations are acceptable and justifiable. This includes the value of time, VOCs, and percentages of cars and trucks on the streets and freeways. There must also be consistency between the various methods to determine the user cost estimate.

6.2 Applying User Costs

UDOT must decide when user costs will be applied and how they may be adjusted. The engineer should understand the project and make the decision as to whether or not some form of incentive may be needed.

6.3 Flow Chart for Decision Making

The flow chart shown in Figure 6-1 is provided to assist in making the decision of how to determine user costs. This simple flow chart shows the basic steps that UDOT engineers should follow for determining user costs. DUCK should be used first since this is the simplest model and it will give hourly traffic volumes that can be used in DelayE. DUCK is used to determine the cost due to a speed reduction or detour. If the traffic volume is greater than the capacity through the work zone or on a detour, a message will appear informing the user of that fact and suggesting that DelayE should be used. The user should check the total user costs and decide whether the total would be high enough to use for an incentive for this project. If the value is not high enough, then the user should use DelayE. The values for hourly data can be obtained in DUCK. Because DelayE incorporates the use of the queue in its user costs, the estimated cost will be higher than the computed value using DUCK. Any adjustments needed should be made at the end.

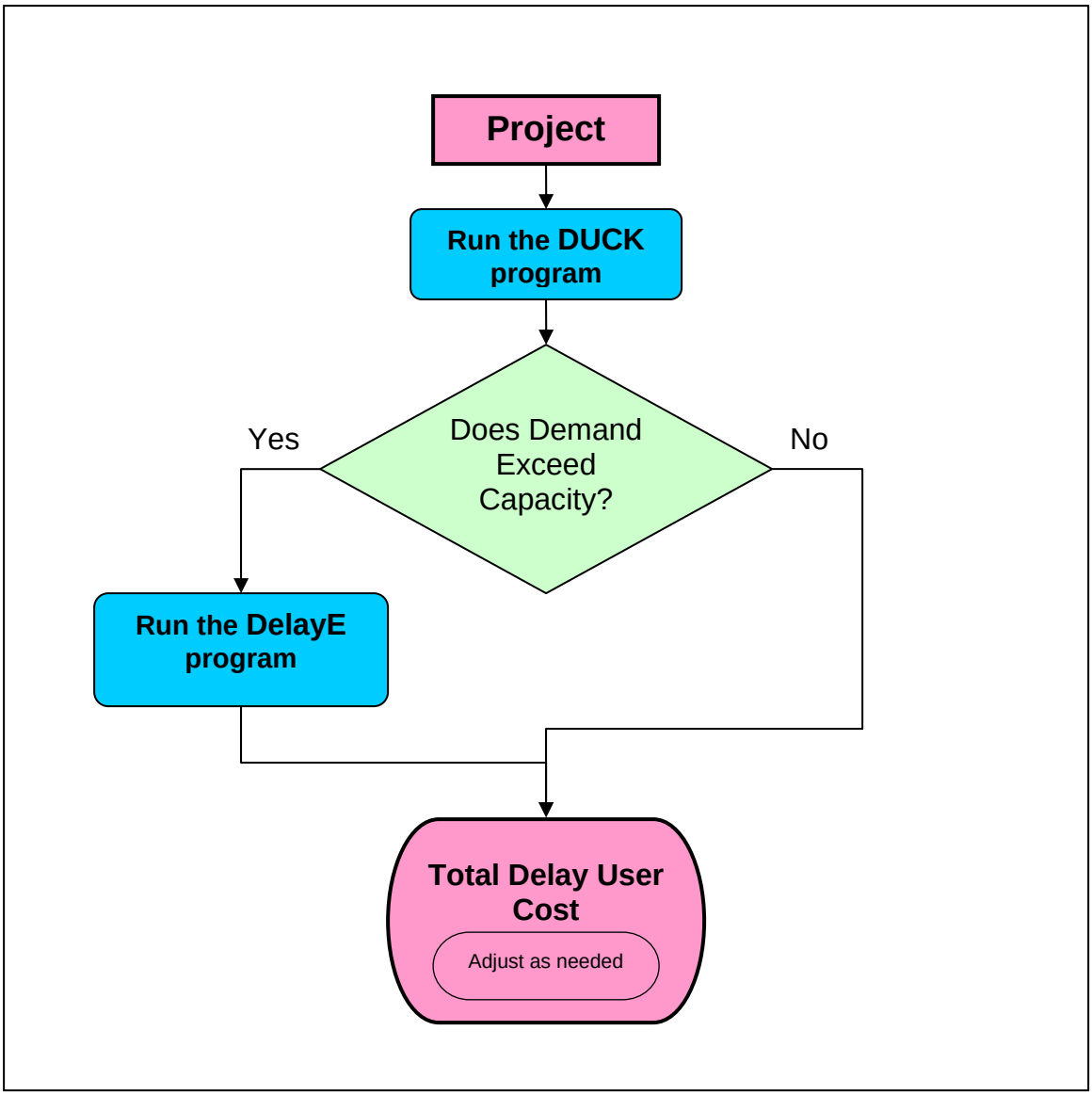


Figure 6-1: Flow Chart for Determining User Costs for UDOT.

6.4 Summary

UDOT must make various decisions with regards to user costs. The first is to ensure that values used are appropriate and justifiable. UDOT engineers must also know when the circumstances of a project are suitable for a user cost estimation application. A

flow chart has been provided to assist in some of the work to apply user costs by directing UDOT personnel in the steps of using DUCK and DelayE.

Chapter 7. Program Description

The previous chapter describes the general plan to find the user costs. This chapter explains how to use DUCK and DelayE and what inputs are needed for the use of the programs.

7.1 Description of DUCK

This section describes how DUCK estimates the total user costs. The first subsections of this section, Project Information, and Route Description, describe the values that should be entered into the DUCK worksheet. The later subsections describe the other worksheets and their functions and how they are used to determine the user cost estimates.

To assist in locating the worksheets, sections, and tables used in DUCK, the following formatting is used to locate where values are used:

- **WORKSHEET** – Worksheet names are written in bold, capital letters.
- **Section** – Names of sections within the worksheets begin with a capital letter and are in bold.

- ***Table*** – Table names are italicized and bold. (Because the **DUCK** worksheet is set up slightly different than the other worksheets, this formatting will be used for the line of data to enter on the **DUCK** worksheet only.)
- *Lower Categories* – Names of lower categories are italicized.

7.1.1 Project Information

Upon opening the Excel file of DUCK, ensure that the **DUCK** worksheet tab is chosen. Figure 7-1 shows the top section of this worksheet for DUCK version 1.3.

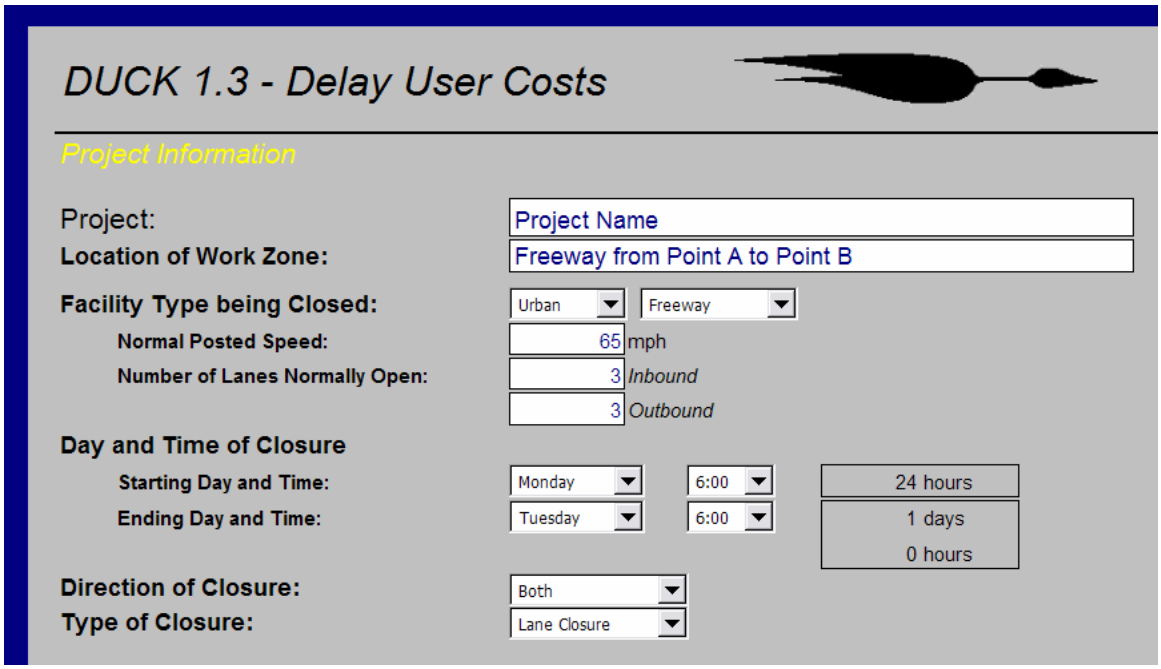


Figure 7-1: Project Information Section on the DUCK Worksheet.

As can be seen in Figure 7-1, the first section is called **Project Information**. This is where general information about the project location is entered. Each value is fairly simple to understand and is explained in the following paragraphs.

Project is where the name of the project should be entered. Just below is ***Location of Work Zone***, where a brief description of the location may be entered. These are to assist in the identification of the project and its location.

The ***Facility Type being Closed*** allows the user to describe the type of facility where the work zone will be located. There are four possible combinations with either "Urban" or "Rural", and "Freeway" or "Arterial." In Figure 7-1 it is shown as an "Urban Freeway." Still under the ***Facility Type being Closed*** are the categories of *Normal Posted Speed* and *Number of Lanes Normally Open*. The *Normal Posted Speed* is the speed limit for this section of the highway under normal conditions without the work zone. The *Number of Lanes Normally Open* is exactly as it is described. The inbound and outbound directions, though, are decided by the user and should correlate with the general flow of traffic throughout the day. A higher volume of vehicles travel in the inbound direction during the morning and a higher volume of vehicles travel in the outbound direction during the evening.

The ***Day and Time of Closure*** is where the day and hour of the beginning and ending of the work zone closure are entered into the program. The pull-down boxes allow the user to choose the day and time, where time is given in 24-hour format. To the right of these boxes is a small display presenting the total number of hours the project closes lanes. Also displayed is the number of days and hours. The days are 24-hour periods beginning with the starting time of the project and do not correspond directly with calendar days.

The ***Direction of Closure*** has three choices: "Inbound," "Outbound," or "Both." The user indicates whether the closure occurs only on the inbound or outbound direction, or on both the inbound and outbound directions.

Finally, the ***Type of Closure*** has two choices: "Lane Closure," or "Full Closure." A "Lane Closure" indicates that the facility will remain open, but a certain number of lanes will be closed to traffic. A "Full Closure" indicates that all lanes of traffic will be closed and all traffic normally on the facility will be directed to a detour route.

In summary, all necessary information in this section must be entered correctly for the program to provide an accurate estimate of user costs. The values entered in this section, along with the values in the following section, Route Description, are used to determine the total user cost estimate.

7.1.2 Route Description

The **Route Description** section allows certain inputs to be entered that provide more detailed descriptions of the work zone route and the detour route. The Work Zone side of the section is described first. Figure 7-2 shows how the **Route Description** section appears containing both the Work Zone and Detour sides of the section.

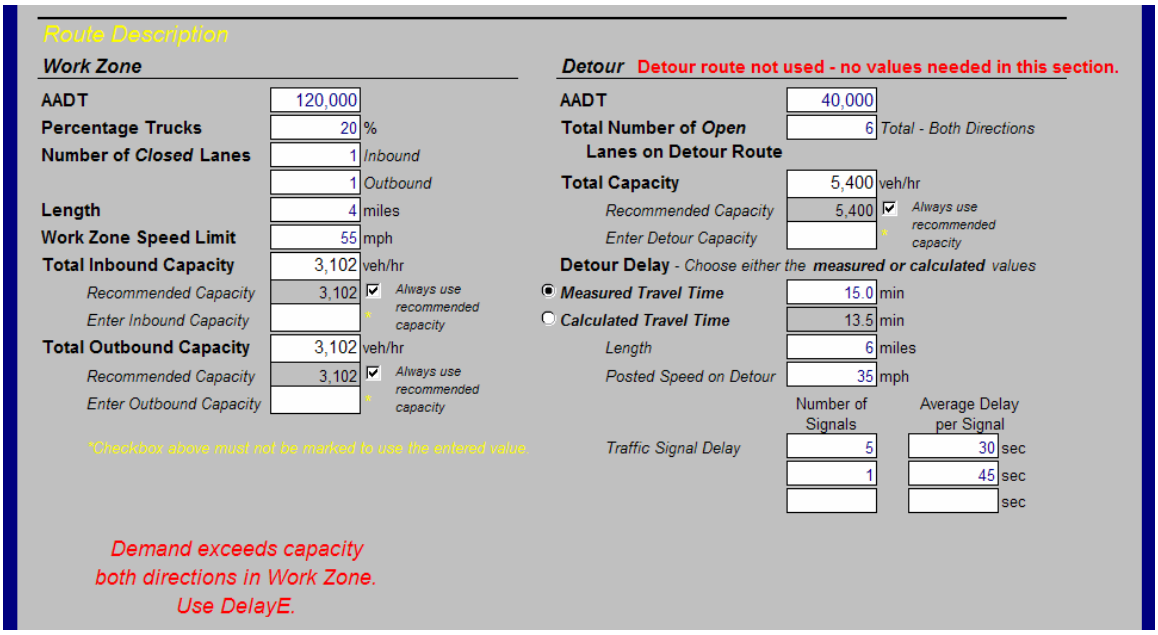


Figure 7-2: Route Description Section of the DUCK Worksheet.

7.1.2.1 Work Zone

The first line, ***AADT***, on the Work Zone side of this section, is where the annual average daily traffic (AADT) on the facility is entered. This value can be determined from data provided by UDOT permanent count stations located near the work zone or from counts taken directly for the project. AADTs are available on UDOT's website.

The ***Percentage Trucks*** line is to enter the percentage of vehicles on the route that are trucks.

The ***Number of Closed Lanes*** are those lanes closed due to the highway construction project. These numbers may be different for both the inbound and outbound directions. If the closure only affects one direction, then only that number needs to be provided. If the number of lanes closed is entered for both the inbound and outbound directions, the program only uses the numbers for the direction of the closure specified in

the **Project Information** section. No values need to be entered here if there is a full closure, but if they are entered, DUCK only uses the values necessary for the calculations.

The ***Length*** is the length of the work zone containing the reduced number of lanes and lower speed limit.

The ***Work Zone Speed Limit*** is the speed limit within the work zone.

The ***Total Inbound Capacity*** and ***Total Outbound Capacity*** are used to determine whether the demand, determined on the **HOURLY DISTRIBUTION** worksheet and explained later, will be greater than the capacity of the facility displayed on these lines. The *Recommended Capacity* is shown here and is determined on the **CAPACITY** worksheet using the number of lanes normally open and the number of lanes closed in each direction. This variable is also described later. If the checkbox is marked, then the *Recommended Capacity* will be used. If a capacity different than the *Recommended Capacity* is to be used, then the value is entered on the line called *Enter Inbound Capacity* or *Enter Outbound Capacity*, and the checkbox labeled, *Always use recommended capacity* must be unchecked.

If the demand in the work zone is greater than the capacity, a message is displayed indicating that the demand is greater than the capacity and that DelayE should be used to compute the delay caused by queues, as shown in Figure 7-3.

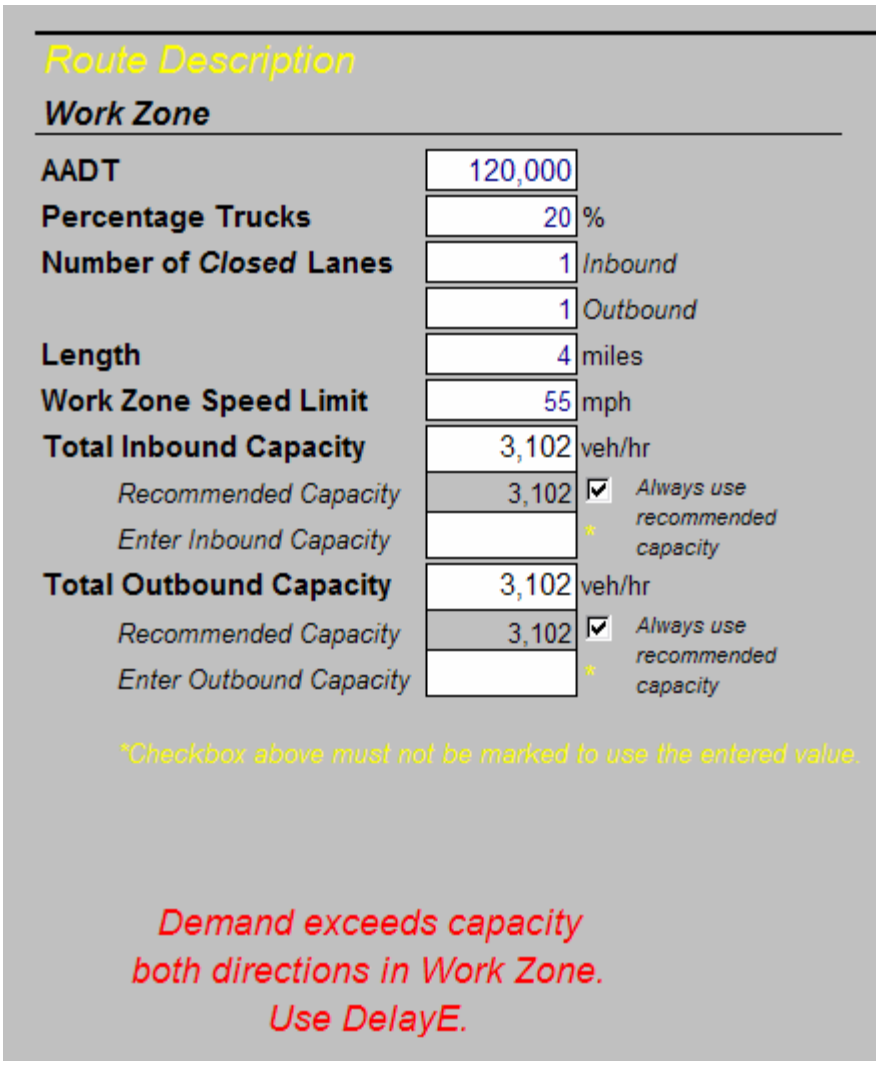


Figure 7-3: Message Indicating that Demand Exceeds the Capacity.

As illustrated in Figure 7-3, a message directing the user to use DelayE is shown below the rest of the values entered. The message will be adjusted according to the ***Direction of Closure*** under **Project Information**. The three possible messages are as follows:

- Inbound demand exceeds capacity in Work Zone. Use DelayE.
- Outbound demand exceeds capacity in Work Zone. Use DelayE.
- Demand exceeds capacity both directions in Work Zone. Use DelayE.

7.1.2.2 Detour

If the ***Type of Closure*** is chosen to be "Lane Closure," a message is given on the Detour side of this section, next to the title "Detour," which reads "Detour route not used – no values needed in this section," to inform the user that no information is needed in this section. This message is seen in Figure 7-4. The message does not appear if "Full Closure" is selected, and the necessary data should be entered. If, however, values are entered into the boxes, they will not be used unless "Full Closure" has been selected.

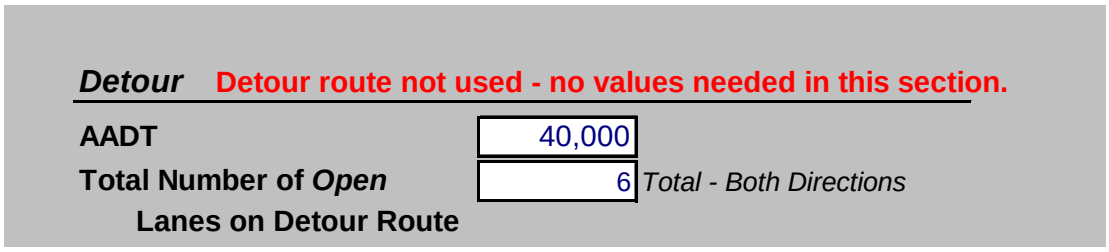


Figure 7-4: Message Indicating the Detour Portion of the Route Description Section Does Not Need Values Entered.

As seen in Figure 7-5, some of the lines are similar to those on the Work Zone side of the **Route Description** section. There are some key differences, though. The Detour side of this section is used to describe the detour route where traffic is directed to travel if there is a full closure, as indicated on the ***Type of Closure*** line on the **Project Information** section.

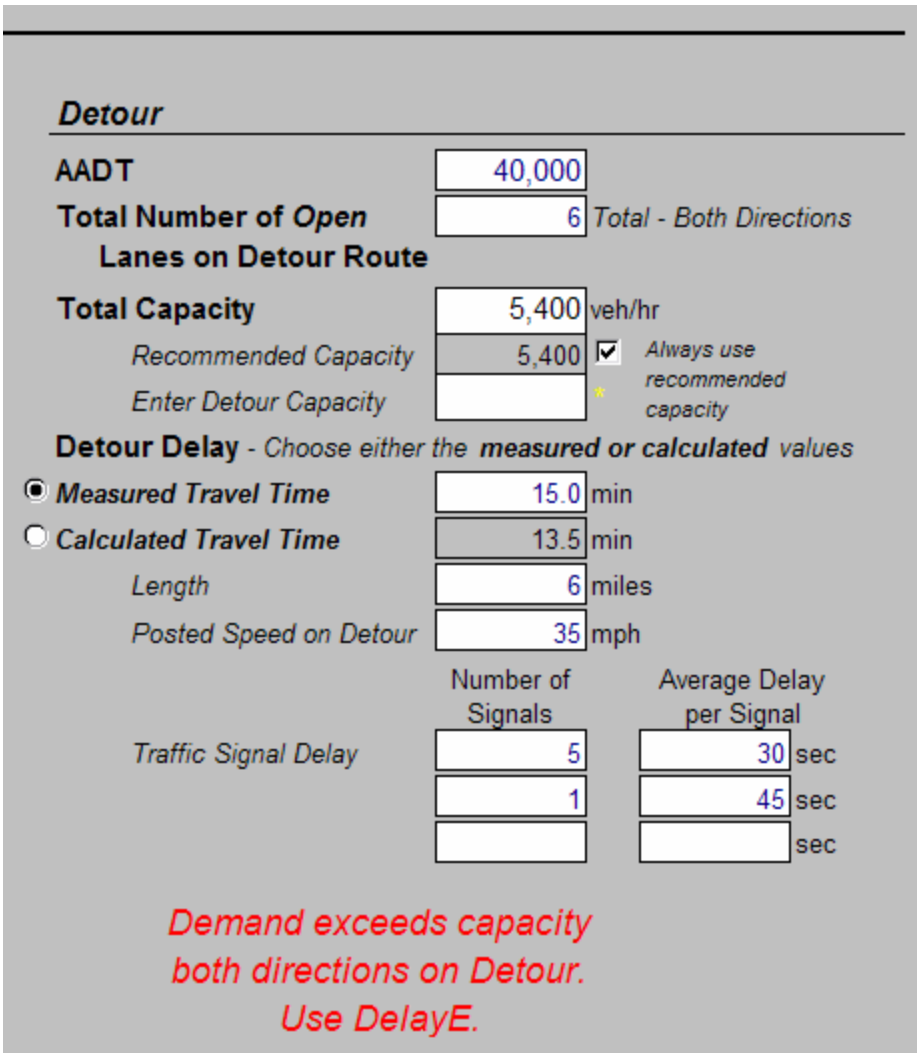


Figure 7-5: Detour Portion of the Route Description Section.

The Detour ***AADT*** is the AADT volume normally on the detour route. The traffic normally on the detour route is not added to the traffic from the work zone, now traveling on the detour route, to determine the amount of lost time and the total user cost. Instead, the AADT normally on the detour route is used only to determine whether the demand, consisting of the normal volume on the street plus the volume of vehicles using it as a detour route, exceeds the capacity of the detour route.

The ***Total Number of Open Lanes on Detour Route*** line is for the total number of through lanes on the facility in both directions. If there are two lanes in each direction, then "4" would be entered. If there are three lanes in each direction, "6" would be entered.

The ***Total Capacity*** is the total capacity for both directions. The *Recommended Capacity* and *Enter Detour Capacity* boxes are similar to those described for the Work Zone ***Total Capacity***.

The next line, ***Detour Delay***, is used to determine the amount of time needed to travel along the detour route. This value is compared to the time normally needed to travel the distance on the route where the work zone will be set up to determine the difference in travel times. There are two ways to determine the ***Detour Delay***. The first is by the *Measured Travel Time*. This value is determined by actually traveling and timing the distance. The second is by using the *Calculated Travel Time*. The program will calculate the travel time by using the length of the detour route and the posted speed on the detour. Using these two values, the program can determine the time needed for drivers to travel that distance. In addition, surface streets have traffic signals that may increase the travel time due to signal delay. Therefore, the traffic signal delay needs to be entered. There are three rows for values to be entered, although not all of the rows must be used. There are two columns, Number of Signals and Average Delay per Signal. The Number of Signals is the number of signals that have the same amount of average delay per signal. The average delay per signal is entered in the second column. The cells are set up to read as, "There are X signals, each with Y seconds of delay." The three rows are provided for three different values of average delay per signal. Using the length,

speed, and signal delay, the program calculates the travel time along the detour route and displays the value on the line with *Calculated Travel Time*. The option buttons to the left of *Measured Travel Time* and *Calculated Travel Time* allow the user to choose which travel time the program should use to calculate the total user cost estimate.

Similar to the Work Zone side of this section, a message may appear indicating that DelayE should be used if the demand is greater than the capacity of the detour route. This message was shown previously in Figure 7-5. The possible messages are as follows:

- Inbound demand exceeds capacity on Detour. Use DelayE.
- Outbound demand exceeds capacity on Detour. Use DelayE.
- Demand exceeds capacity both directions on Detour. Use DelayE.

7.1.2.3 Summary of Route Description

All needed information has now been entered into the program, from both the **Project Information** section and **Route Description** section, and the results may be seen at the bottom of the **DUCK** worksheet.

7.1.3 Results Section

The **Results** section displays the results for the ***Total Delay Cost for Analysis Period*** as well as results from some of the intermediate steps in determining the ***Total Delay Cost***, such as the travel time, number of vehicles, and lost time. Figure 7-6 provides an illustration of the **Results** section.

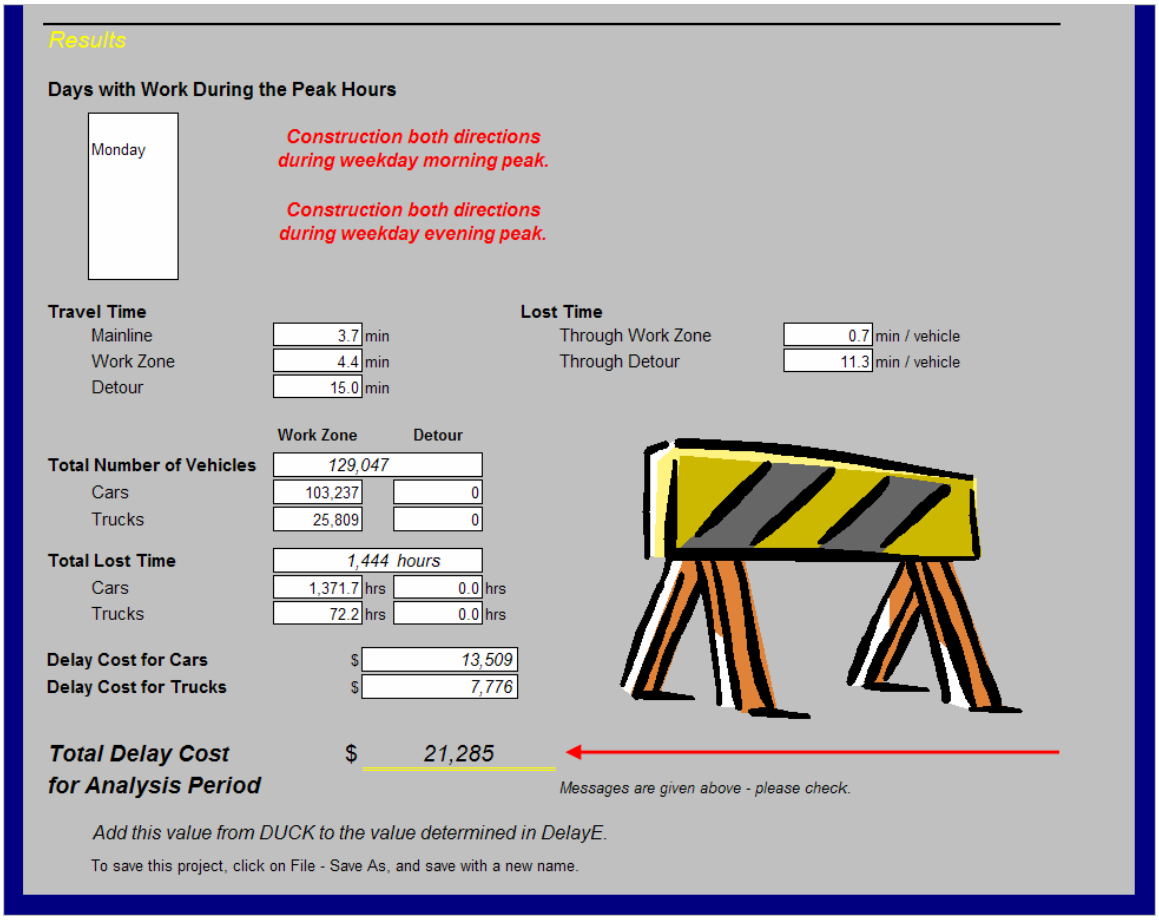


Figure 7-6: Results Section on the DUCK Worksheet.

The ***Days with Work During the Peak Hours*** shows only those days where there is a closure during the peak hours of that day. As was illustrated previously in Figure 7-1, the closure is from Monday at 6:00 to Tuesday at 6:00. Although there are hours on Tuesday that contain a closure, they do not exist during the peak hours of the day, while on Monday there are closures during the morning and evening peak hours. As Figure 7-6 illustrates, there are possible messages shown to the right of these days indicating that construction is during the peak hours.

The ***Travel Time***, ***Lost Time***, ***Total Number of Vehicles***, ***Total Lost Time***, ***Delay Cost for Cars***, and ***Delay Cost for Trucks*** values displayed here are intermediate steps to

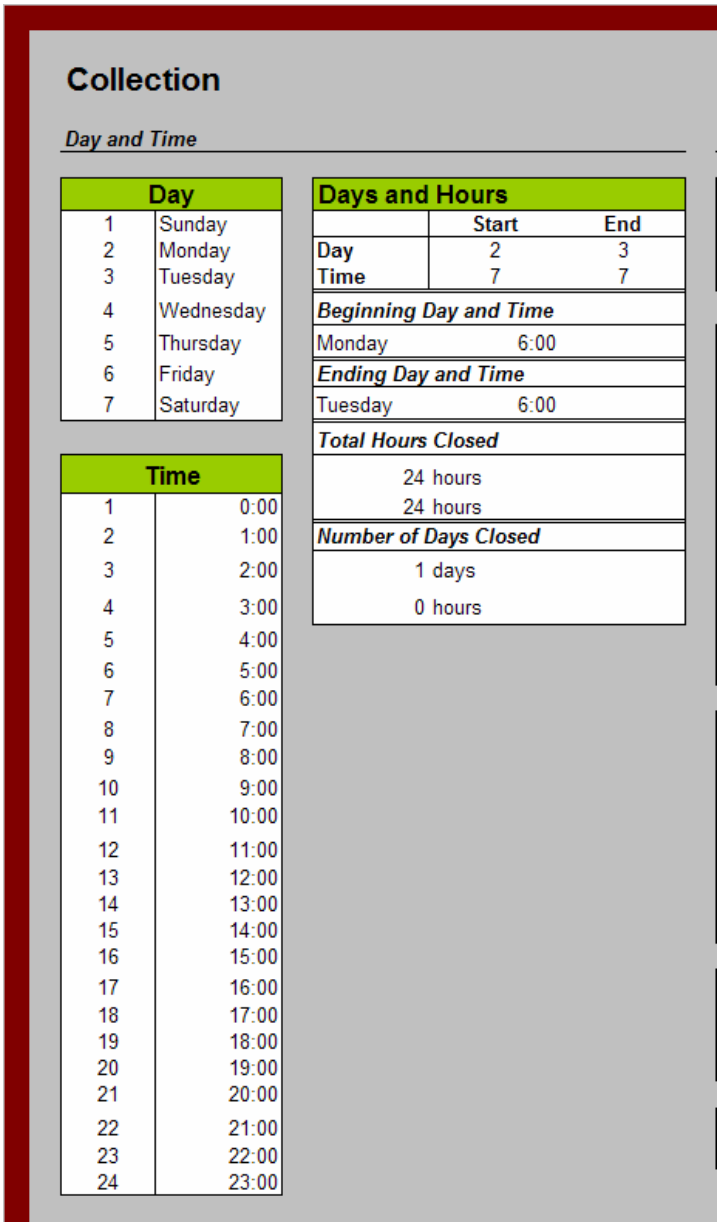
the final ***Total Delay Cost for Analysis Period*** and are determined on other worksheets. Greater details of the values displayed here are explained in upcoming sections.

7.1.4 Collection

The **COLLECTION** worksheet is where values are gathered together and then forwarded to various other worksheets in the program. To assist the user in better understanding how the values are calculated, this section describes what is accomplished on the **COLLECTION** worksheet.

7.1.4.1 Day and Time

The **Day and Time** section on the COLLECTION worksheet, shown in Figure 7-7, contains tables for the Excel functions to look up the correct value and then display the day and time. The ***Day*** table contains a number and all days of the week. The ***Time*** table contains a number and the starting time of each hour in the day. In the third table, ***Days and Hours***, the start and end of the day and time are displayed as numbers corresponding to the numbers on the ***Day*** and ***Time*** tables. These are then converted into the written day and time for the start and end of the time period. The information in these tables is then used to determine the number of hours over which the construction project will occur.



Collection

Day and Time

Day	
1	Sunday
2	Monday
3	Tuesday
4	Wednesday
5	Thursday
6	Friday
7	Saturday

Time	
1	0:00
2	1:00
3	2:00
4	3:00
5	4:00
6	5:00
7	6:00
8	7:00
9	8:00
10	9:00
11	10:00
12	11:00
13	12:00
14	13:00
15	14:00
16	15:00
17	16:00
18	17:00
19	18:00
20	19:00
21	20:00
22	21:00
23	22:00
24	23:00

Days and Hours		
	Start	End
Day	2	3
Time	7	7
Beginning Day and Time		
Monday	6:00	
Ending Day and Time		
Tuesday	6:00	
Total Hours Closed		
24 hours		
24 hours		
Number of Days Closed		
1 days		
0 hours		

Figure 7-7: Day and Time Section on the Collection Worksheet.

7.1.4.2 Facility and Route

The **Facility and Route** section, shown in Figure 7-8, contains the description data entered for the various routes, the mainline normally open, the work zone, and the detour route for the inbound and outbound directions.

Facility and Route

Facility Type			
1	Urban	1	Freeway
2	Rural	2	Arterial
1	*Urban*	*1*	*Freeway*

Route Descriptions				
	Mainline			
Length	4			
Speed	65			
Lanes Open	3	*Inbound*		
	3	*Outbound*		
	Work Zone			**Detour**
Length	4		**Length**	6
Speed	55		**Speed**	35
Lanes Closed	1	*Inbound*	**Lanes Open**	6
	1	*Outbound*		

Direction and Type of Closure			
1	Inbound	3	*Both*
2	Outbound		
3	Both		
Lane Closure		*Lane Closure*	
Full Closure		1	0
Inputs - Detour Message			
Detour route not used - no values needed in this section.			

Capacity	
Work Zone - Inbound	3,102
Work Zone - Outbound	3,102
Detour	5,400

% AADT taking Detour
0

Figure 7-8: Facility and Route Section on the Collection Worksheet.

The ***Facility Type*** table contains the numerical values for the *Urban* and *Rural* locations, and the *Freeway* or *Arterial* facility types. The bottom of this table contains the description that has been chosen on the **DUCK** page.

The ***Route Description*** table gathers all the information entered into the **DUCK** page in the **Project Information** and **Route Description** sections.

The ***Direction and Type of Closure*** table contains a list of the possible choices for the closure—inbound, outbound, or both—on the left side of the table. The right side of the table displays the direction of closure chosen. The next portion of the table then contains the types of closures, and to the right displays the type of closure selected for use. At the very bottom of this table is another section named *Input—Detour Message*, which will display the message "Detour route not used—no values needed in this section," if a lane closure is used for the project.

The next table is named ***Capacity***. The values come from the inputs on the **DUCK** worksheet and are computed on the **CAPACITY** worksheet.

The last table, ***% AADT Taking Detour***, shows the percentage of the traffic taking the detour. With only a lane closure, the value is 0, indicating that all traffic stays on the mainline through the work zone. The value is 100 with a full closure, indicating that all traffic must exit the freeway and take the detour. For simplifying the calculations, all traffic is considered to either stay on the freeway with a lane closure, or to take a detour after exiting the freeway for a full closure.

7.1.4.3 Total Vehicles and Lost Time

The next section, **Total Vehicles and Lost Time**, includes the vehicles that are affected by the work zone and the time lost to delays for these vehicles. This section is illustrated in Figure 7-9.

Total Vehicles and Lost Time

AADT	
Work Zone	120,000
Detour	40,000

% Trucks	
Work Zone	20

Traffic Adjustments	
FALSE	Urban
FALSE	Rural
FALSE	Hourly - Weekday
FALSE	Hourly - Weekend

Total Vehicles		
	Work Zone	**Detour**
Cars	103,237	0
Trucks	25,809	0
Total	*129,047*	

Measured Travel Time	
15.00	min

Calculated Travel Time		
Traffic Signal Delay		
195	sec	
Total Detour	13.54	min

Travel Time		
Mainline	3.69	min
Work Zone	4.36	min
Detour		
1	15.00	min
Travel Time Difference		
Work Zone	0.67	min
Detour	11.31	min

Total Lost Time		
	Work Zone	**Detour**
Cars	1,155.1	0.0
Trucks	288.8	0.0
Total	1,443.9	0.0
Grand Total	*1,443.9*	

Figure 7-9: Total Vehicles and Lost Time Section on the Collection Worksheet.

The ***AADT*** and ***% Trucks*** tables are simply the values entered into the program on the **DUCK** page. The next table, ***Traffic Adjustments***, refers to another worksheet, **TRAFFIC ADJUSTMENTS**, in which the user can change the hourly and daily distribution of traffic. This table on the **COLLECTION** page is simply the place for the program to display the true or false choices relating to the checkboxes on the **TRAFFIC ADJUSTMENTS** worksheet.

The ***Measured Travel Time*** is a value entered by the user indicating the time needed to travel the distance of the detour route. This value can be determined by driving and timing the distance. The adjacent table, ***Calculated Travel Time***, calculates the travel time by dividing the distance by the speed limit, multiplying by 60, and then adding the result to traffic signal delay, as shown in Equation 7-1. The *Traffic Signal Delay* is calculated by multiplying the number of signals by the average delay in seconds at those signals.

$$CTT = \frac{Dist * 60}{Speed} + \frac{SignalDelay}{60} \qquad \textbf{(7-1)}$$

where,

CTT = calculated travel time (minutes),

Dist = distance of the detour (miles),

Speed = speed limit on the detour (miles/hour), and

SignalDelay = delay caused by traffic signals on the detour route (seconds).

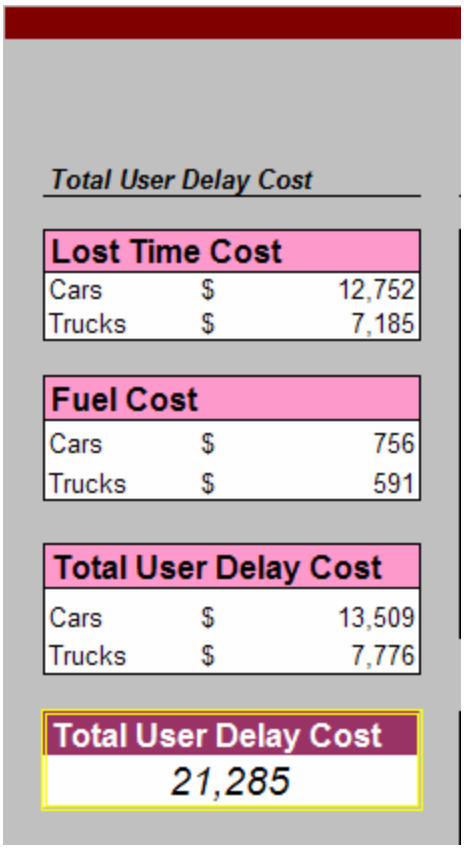
The ***Travel Time*** table displays the travel times for the mainline, work zone, and detour. The mainline and work zone travel times are determined by dividing the length

by the speed limit. The detour travel time was already explained in the ***Calculated Travel Time*** table. The *Travel Time Difference* subtracts the mainline travel time from the work zone and detour travel times. This value is later multiplied by the number of vehicles affected by the lane closure to determine the total lost time.

The ***Total Lost Time*** table multiplies the number of vehicles, cars and trucks, by the amount of time lost. Adding the values for the cars and trucks together provides the grand total for the total lost time. These values are calculated on the **COSTS** worksheet, which is described later.

7.1.4.4 Total User Delay Cost

The section of **Total User Delay Cost** gathers the values that were calculated from the **COSTS** worksheet, which is described later. The tables show the ***Lost Time Cost***, the ***Fuel Cost***, and the ***Total User Delay Cost*** as illustrated in Figure 7-10.



Total User Delay Cost

Lost Time Cost		
Cars	$	12,752
Trucks	$	7,185

Fuel Cost		
Cars	$	756
Trucks	$	591

Total User Delay Cost		
Cars	$	13,509
Trucks	$	7,776

Total User Delay Cost
21,285

Figure 7-10: Total User Delay Cost Section on the Collection Worksheet.

7.1.4.5 Messages

The ***Messages*** table, shown in Figure 7-11, reveals the messages that are also displayed on the **DUCK** worksheet. Messages displaying a notification when work occurs during the peak hours are generated by searching through the ***Work During Peak Hour*** table and finding a time period when the table displays that there is work during the peak period. Messages originate from the **HOURLY DISTRIBUTION** worksheet, which is described later.

Messages

Messages	
24 hours	Number of hours of construction
Demand exceeds capacity both directions in Work Zone. Use De	Capacity in Work Zone Capacity on Detour
Construction both directions during weekday morning peak. Construction both directions during weekday evening peak.	Weekday Morning Weekday Evening Sunday Afternoon Saturday Afternoon
Messages are given above - please check.	Messages Above
Add this value from DUCK to the value determined in DelayE.	Add to DelayE

Work during Peak Hour		
FALSE		WD In Morn
FALSE		WD In Even
FALSE		WD Out Morn
FALSE		WD Out Even
TRUE	Construction both directions during weekday morning peak.	WD Both Morn
TRUE	Construction both directions during weekday evening peak.	WD Both Even
FALSE		Sunday In
FALSE		Sunday Out
FALSE		Sunday Both
FALSE		Saturday In
FALSE		Saturday Out
FALSE		Saturday Both

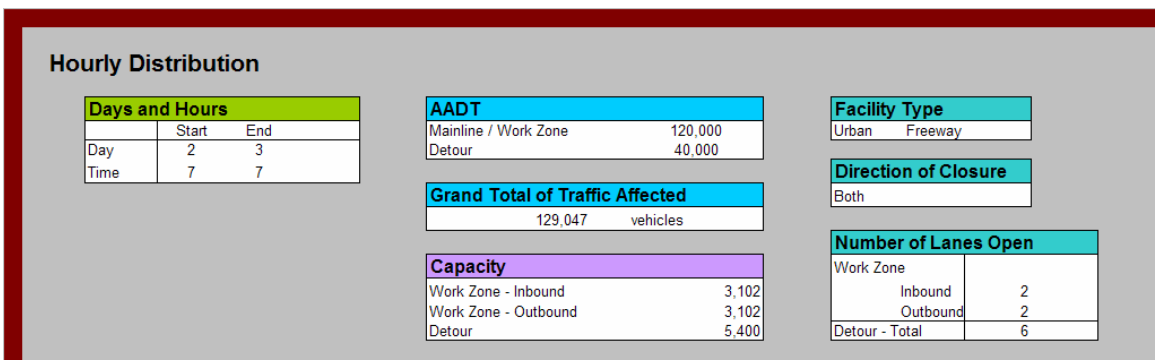
Figure 7-11: Messages Section on the Collection Worksheet.

7.1.4.6 Summary

The **COLLECTION** worksheet provides a location to gather and distribute the various values used throughout the program. This reduces the possibility of altering formulas accidentally on the front page of **DUCK** and provides a location where many of the values may be seen at one time.

7.1.5 Hourly Distribution

The main function of the **HOURLY DISTRIBUTION** worksheet is to calculate the number of vehicles traveling in both the inbound and outbound directions during each hour of the week. The distribution is made for both the mainline/work zone and for the detour route separately. Using the total distribution for all hours as a basis, the remaining tables display the hourly distribution values for certain hours or days depending on when the project is occurring. Messages indicating if the demand exceeds the capacity are determined using these values. The tables near the top of this worksheet, shown in Figure 7-12, contain the data entered into the program from the **DUCK** worksheet.



Hourly Distribution

Days and Hours	Start	End
Day	2	3
Time	7	7

AADT	
Mainline / Work Zone	120,000
Detour	40,000

Grand Total of Traffic Affected	
129,047	vehicles

Capacity	
Work Zone - Inbound	3,102
Work Zone - Outbound	3,102
Detour	5,400

Facility Type	
Urban	Freeway

Direction of Closure
Both

Number of Lanes Open	
Work Zone	
Inbound	2
Outbound	2
Detour - Total	6

Figure 7-12: Top Portion of the Hourly Distribution Worksheet.

7.1.5.1 Mainline/Workzone

The **Mainline/Workzone** section, shown in Figure 7-13, contains the hourly traffic distribution for the mainline and work zone. The first table, ***Calculated Traffic Numbers***, shows the hourly distribution for all hours and days of the week. The values in the ***Calculated Traffic Numbers*** table are determined using Equation 7-2.

Mainline / Work Zone

Calculated Traffic Numbers

		1		2		3		4		5		6		7		Hourly %			
		Sunday		*Monday*		*Tuesday*		*Wednesday*		*Thursday*		*Friday*		*Saturday*		Weekday		Weekend	
		In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
1	*0:00*	535	644	355	484	355	484	355	484	355	484	355	484	759	913	*0.28*	*0.38*	*0.67*	*0.80*
2	*1:00*	366	386	206	265	206	265	206	265	206	265	206	265	519	548	*0.16*	*0.21*	*0.46*	*0.48*
3	*2:00*	201	165	161	135	161	135	161	135	161	135	161	135	285	234	*0.13*	*0.11*	*0.25*	*0.21*
4	*3:00*	177	133	187	110	187	110	187	110	187	110	187	110	251	188	*0.15*	*0.09*	*0.22*	*0.17*
5	*4:00*	173	85	387	116	387	116	387	116	387	116	387	116	245	120	*0.30*	*0.09*	*0.22*	*0.11*
6	*5:00*	370	80	1,387	297	1,387	297	1,387	297	1,387	297	1,387	297	525	114	*1.08*	*0.23*	*0.46*	*0.10*
7	*6:00*	708	245	4,148	1,335	4,148	1,335	4,148	1,335	4,148	1,335	4,148	1,335	1,004	348	*3.22*	*1.04*	*0.88*	*0.31*
8	*7:00*	1,272	986	5,923	2,884	5,923	2,884	5,923	2,884	5,923	2,884	5,923	2,884	1,803	1,398	*4.59*	*2.24*	*1.58*	*1.23*
9	*8:00*	1,847	1,557	5,097	3,787	5,097	3,787	5,097	3,787	5,097	3,787	5,097	3,787	2,620	2,209	*3.95*	*2.94*	*2.30*	*1.94*
10	*9:00*	2,121	1,940	3,748	3,710	3,748	3,710	3,748	3,710	3,748	3,710	3,748	3,710	3,008	2,751	*2.91*	*2.88*	*2.64*	*2.41*
11	*10:00*	2,330	2,253	3,342	3,336	3,342	3,336	3,342	3,336	3,342	3,336	3,342	3,336	3,304	3,196	*2.59*	*2.59*	*2.90*	*2.80*
12	*11:00*	2,596	2,756	3,342	3,458	3,342	3,458	3,342	3,458	3,342	3,458	3,342	3,458	3,681	3,909	*2.59*	*2.68*	*3.23*	*3.43*
13	*12:00*	3,203	3,038	3,432	3,736	3,432	3,736	3,432	3,736	3,432	3,736	3,432	3,736	4,543	4,309	*2.66*	*2.90*	*3.98*	*3.78*
14	*13:00*	2,970	3,038	3,439	3,877	3,439	3,877	3,439	3,877	3,439	3,877	3,439	3,877	4,212	4,309	*2.67*	*3.01*	*3.69*	*3.78*
15	*14:00*	2,696	3,034	3,639	4,181	3,639	4,181	3,639	4,181	3,639	4,181	3,639	4,181	3,824	4,303	*2.82*	*3.24*	*3.35*	*3.77*
16	*15:00*	2,809	3,062	3,865	4,658	3,865	4,658	3,865	4,658	3,865	4,658	3,865	4,658	3,984	4,343	*3.00*	*3.61*	*3.49*	*3.81*
17	*16:00*	2,917	3,839	4,490	5,548	4,490	5,548	4,490	5,548	4,490	5,548	4,490	5,548	4,138	5,445	*3.48*	*4.30*	*3.63*	*4.77*
18	*17:00*	2,938	3,255	4,594	6,168	4,594	6,168	4,594	6,168	4,594	6,168	4,594	6,168	4,166	4,617	*3.56*	*4.78*	*3.65*	*4.05*
19	*18:00*	3,038	2,966	3,858	5,684	3,858	5,684	3,858	5,684	3,858	5,684	3,858	5,684	4,309	4,206	*2.99*	*4.41*	*3.78*	*3.69*
20	*19:00*	2,366	2,463	2,613	3,936	2,613	3,936	2,613	3,936	2,613	3,936	2,613	3,936	3,356	3,493	*2.03*	*3.05*	*2.94*	*3.06*
21	*20:00*	1,771	1,320	1,981	2,794	1,981	2,794	1,981	2,794	1,981	2,794	1,981	2,794	2,511	1,872	*1.54*	*2.17*	*2.20*	*1.64*
22	*21:00*	1,666	785	1,839	2,426	1,839	2,426	1,839	2,426	1,839	2,426	1,839	2,426	2,363	1,113	*1.43*	*1.88*	*2.07*	*0.98*
23	*22:00*	1,179	652	1,239	1,303	1,239	1,303	1,239	1,303	1,239	1,303	1,239	1,303	1,672	925	*0.96*	*1.01*	*1.47*	*0.81*
24	*23:00*	813	736	710	839	710	839	710	839	710	839	710	839	1,153	1,044	*0.55*	*0.65*	*1.01*	*0.92*
Urban		*67.1*		*107.5*		*107.5*		*107.5*		*107.5*		*107.5*		*95.1*					

Figure 7-13: Mainline/Work Zone Section of the Hourly Distribution Worksheet.

$$CTN = AADT * \frac{\%AADTperDay}{100} * \frac{HA}{100} \qquad \textbf{(7-2)}$$

where,

CTN = calculated traffic numbers,

AADT = annual average daily traffic,

%AADTperDay = percentage of the AADT during that day, and

HA = hourly adjustment for the percentage of the daily traffic during that hour.

The values in the ***Calculated Traffic Numbers*** table are hourly volume rates adjusted by the percentage of AADT per day, found at the bottom of the table for each day, and by the hourly adjustments found on the right side of the table. The percentage

of AADT per day and hourly adjustment values are from the **TRAFFIC ADJUSTMENTS** worksheet. More about that worksheet is explained later.

This first table, ***Calculated Traffic Numbers***, is used as the basis for the remaining tables under it. The cells of each of the tables underneath the first table search through the first table and display the corresponding values for the day and time according to what that particular table is programmed to display. The title on each table indicates which hours are displayed. A zero is displayed if there is no closure during that hour. Values for both the inbound and outbound directions are always displayed whether or not the closure is only for the inbound, outbound, or both directions. The distinction between the directions of closure for calculating the user cost is made on the **COSTS** worksheet, which is discussed later, and displays only the actual hours that will be used for the closure.

7.1.5.2 Detour

The **Detour** section, shown in Figure 7-14, contains tables similar to those of the **Mainline/Workzone** section. The only difference is that the ***Calculated Traffic Numbers*** are determined using the AADT for the detour route rather than the AADT for the mainline. The tables under the first table are also similar to those of the **Mainline/Workzone** section.

Detour

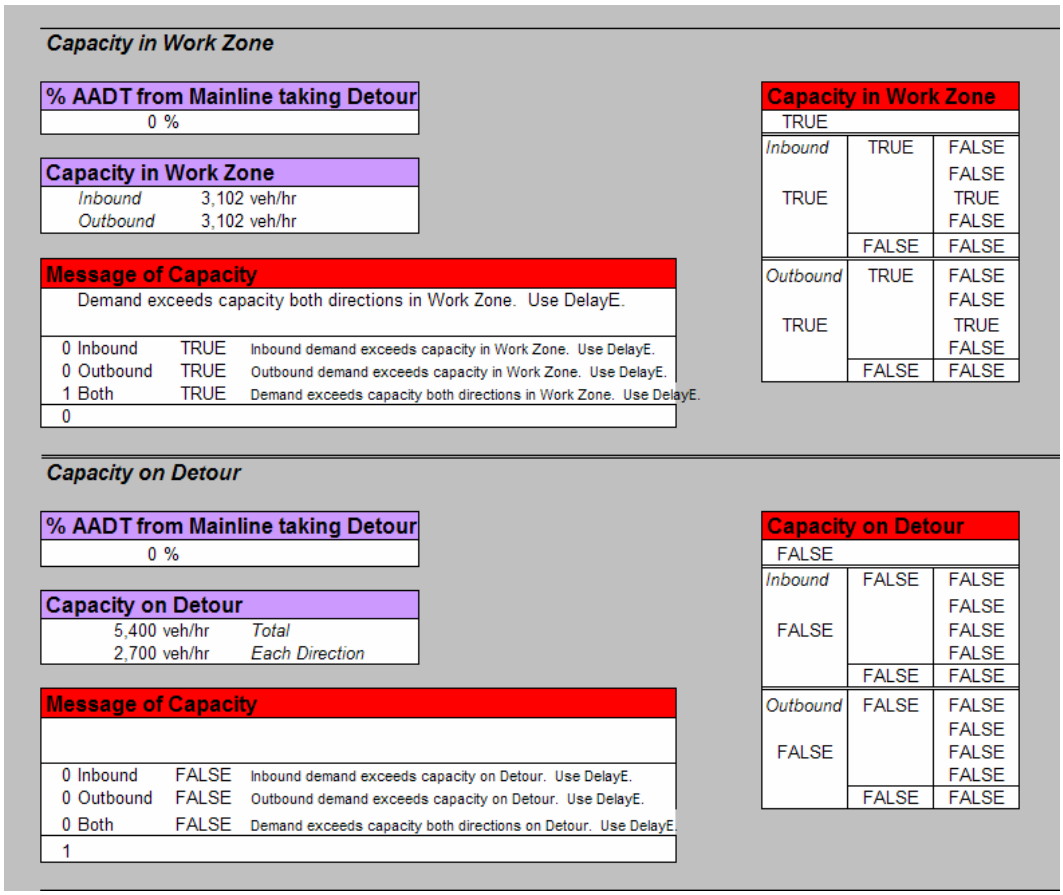
Calculated Traffic Numbers																					
		1		2		3		4		5		6		7		Hourly %			
		Sunday		*Monday*		*Tuesday*		*Wednesday*		*Thursday*		*Friday*		*Saturday*		Weekday		Weekend	
		In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
1	*0:00*	161	259	116	239	116	239	116	239	116	239	116	239	228	367	*0.27*	*0.56*	*0.60*	*0.97*
2	*1:00*	94	185	65	120	65	120	65	120	65	120	65	120	133	263	*0.15*	*0.28*	*0.35*	*0.69*
3	*2:00*	54	107	49	73	49	73	49	73	49	73	49	73	76	152	*0.12*	*0.17*	*0.20*	*0.40*
4	*3:00*	46	52	47	54	47	54	47	54	47	54	47	54	65	74	*0.11*	*0.13*	*0.17*	*0.20*
5	*4:00*	44	40	120	65	120	65	120	65	120	65	120	65	63	57	*0.28*	*0.15*	*0.17*	*0.15*
6	*5:00*	91	52	340	138	340	138	340	138	340	138	340	138	129	74	*0.79*	*0.32*	*0.34*	*0.20*
7	*6:00*	219	105	1,101	303	1,101	303	1,101	303	1,101	303	1,101	303	310	148	*2.56*	*0.71*	*0.82*	*0.39*
8	*7:00*	350	251	2,234	606	2,234	606	2,234	606	2,234	606	2,234	606	497	356	*5.20*	*1.41*	*1.31*	*0.94*
9	*8:00*	541	392	2,138	776	2,138	776	2,138	776	2,138	776	2,138	776	767	556	*4.97*	*1.81*	*2.02*	*1.46*
10	*9:00*	644	539	1,488	806	1,488	806	1,488	806	1,488	806	1,488	806	913	765	*3.46*	*1.88*	*2.40*	*2.01*
11	*10:00*	812	751	1,200	955	1,200	955	1,200	955	1,200	955	1,200	955	1,151	1,065	*2.79*	*2.22*	*3.03*	*2.80*
12	*11:00*	867	931	1,213	1,252	1,213	1,252	1,213	1,252	1,213	1,252	1,213	1,252	1,229	1,320	*2.82*	*2.91*	*3.23*	*3.47*
13	*12:00*	928	1,041	1,344	1,495	1,344	1,495	1,344	1,495	1,344	1,495	1,344	1,495	1,316	1,476	*3.13*	*3.48*	*3.46*	*3.88*
14	*13:00*	979	999	1,348	1,370	1,348	1,370	1,348	1,370	1,348	1,370	1,348	1,370	1,389	1,417	*3.14*	*3.19*	*3.65*	*3.73*
15	*14:00*	865	993	1,282	1,462	1,282	1,462	1,282	1,462	1,282	1,462	1,282	1,462	1,227	1,408	*2.98*	*3.40*	*3.23*	*3.70*
16	*15:00*	872	1,017	1,247	1,800	1,247	1,800	1,247	1,800	1,247	1,800	1,247	1,800	1,237	1,442	*2.90*	*4.19*	*3.25*	*3.79*
17	*16:00*	889	1,003	1,241	2,144	1,241	2,144	1,241	2,144	1,241	2,144	1,241	2,144	1,261	1,423	*2.89*	*4.99*	*3.32*	*3.74*
18	*17:00*	852	958	1,241	2,305	1,241	2,305	1,241	2,305	1,241	2,305	1,241	2,305	1,208	1,358	*2.89*	*5.36*	*3.18*	*3.57*
19	*18:00*	1,061	849	1,168	1,598	1,168	1,598	1,168	1,598	1,168	1,598	1,168	1,598	1,505	1,204	*2.72*	*3.72*	*3.96*	*3.17*
20	*19:00*	954	660	888	1,056	888	1,056	888	1,056	888	1,056	888	1,056	1,353	936	*2.07*	*2.46*	*3.56*	*2.46*
21	*20:00*	457	514	533	830	533	830	533	830	533	830	533	830	649	729	*1.24*	*1.93*	*1.71*	*1.92*
22	*21:00*	468	991	510	826	510	826	510	826	510	826	510	826	664	1,406	*1.19*	*1.92*	*1.75*	*3.70*
23	*22:00*	435	706	432	723	432	723	432	723	432	723	432	723	616	1,001	*1.01*	*1.68*	*1.62*	*2.63*
24	*23:00*	283	463	260	406	260	406	260	406	260	406	260	406	401	656	*0.61*	*0.95*	*1.06*	*1.73*
Urban		67.1		107.5		107.5		107.5		107.5		107.5		95.1					

Figure 7-14: Detour Section of the Hourly Distribution Worksheet.

7.1.5.3 Capacity

To the far right of this worksheet are two sections, ***Capacity in Work Zone*** and ***Capacity on Detour***, as shown in Figure 7-15. These sections determine whether the capacity of the work zone and the capacity of the detour can accommodate the vehicles that will be using the particular facility.

The **Capacity in Work Zone** section determines whether messages should be displayed indicating that the demand exceeds the capacity of the facility. The formulas in these cells of the tables search through the tables in the **Mainline/Workzone** section to find values that are greater than those of the capacity for the inbound and outbound directions. If there is even one value for the demand greater than the capacity, a message will be displayed indicating such. This message is also displayed in the **DUCK** worksheet.



Capacity in Work Zone

% AADT from Mainline taking Detour
0 %

Capacity in Work Zone	
Inbound	3,102 veh/hr
Outbound	3,102 veh/hr

Message of Capacity		
Demand exceeds capacity both directions in Work Zone. Use DelayE.		
0 Inbound	TRUE	Inbound demand exceeds capacity in Work Zone. Use DelayE.
0 Outbound	TRUE	Outbound demand exceeds capacity in Work Zone. Use DelayE.
1 Both	TRUE	Demand exceeds capacity both directions in Work Zone. Use DelayE.
0		

Capacity in Work Zone		
TRUE		
Inbound	TRUE	FALSE
		FALSE
TRUE		TRUE
		FALSE
	FALSE	FALSE
Outbound	TRUE	FALSE
		FALSE
TRUE		TRUE
		FALSE
	FALSE	FALSE

Capacity on Detour

% AADT from Mainline taking Detour
0 %

Capacity on Detour	
5,400 veh/hr	*Total*
2,700 veh/hr	*Each Direction*

Message of Capacity		
0 Inbound	FALSE	Inbound demand exceeds capacity on Detour. Use DelayE.
0 Outbound	FALSE	Outbound demand exceeds capacity on Detour. Use DelayE.
0 Both	FALSE	Demand exceeds capacity both directions on Detour. Use DelayE.
1		

Capacity on Detour		
FALSE		
Inbound	FALSE	FALSE
		FALSE
FALSE		FALSE
		FALSE
	FALSE	FALSE
Outbound	FALSE	FALSE
		FALSE
FALSE		FALSE
		FALSE
	FALSE	FALSE

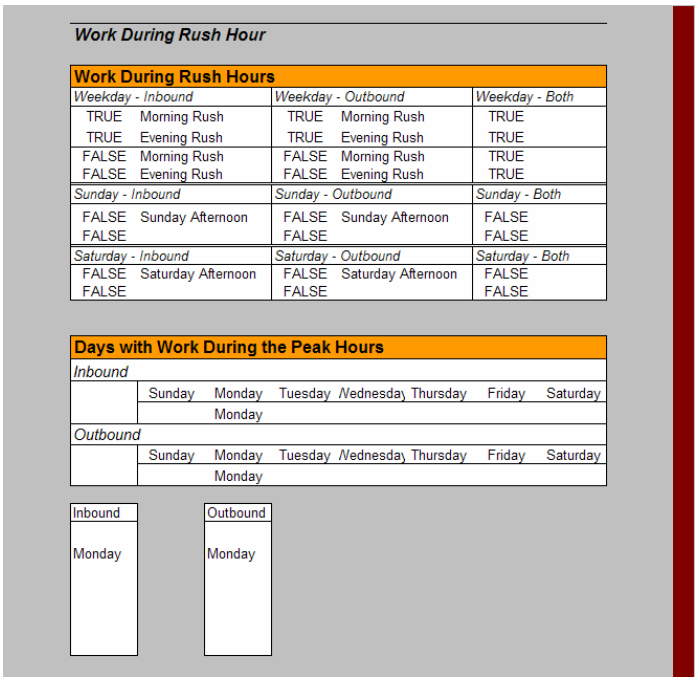
Figure 7-15: Capacity in Work Zone and Capacity on Detour Sections of the Hourly Distribution Worksheet.

The ***Capacity on Detour*** section is similar to the ***Capacity in Work Zone*** section, but with one difference. Under this section are more tables similar to those of the ***Mainline/Workzone*** and ***Detour*** sections, but these tables display the total number of vehicles that are estimated to travel on the detour route during a full closure. These values are based upon the percentages of cars and trucks that are taking the detour. If only a lane closure occurs, no vehicles are assumed to take the detour route, while if a full closure transpires, all vehicles from the work zone are assumed to travel on the detour route with those vehicles that are normally on the detour route. The **Capacity in Work Zone** section searches through these tables for values that are greater than the

capacity of the detour route. Messages may be displayed if the demand is greater than the capacity.

7.1.5.4 Work During Rush Hour

At the far right side of this worksheet is the final section, **Work During Rush Hour**, as shown in Figure 7-16. In this section, the cells in the ***Days with Work During the Peak Hours*** table search through the values in the tables of the **Mainline/Workzone** section to determine if work is performed during peak hours. The peak hours are set to be from 6:00 AM to 9:00 AM and 4:00 PM to 7:00 PM on the weekdays. Satuday and Sunday peak hours are set to be from 12:00 PM to 7:00 PM. Having work during the peak hours does not directly affect the total user cost in the end, except that more vehicles are traveling during that time. Messages are simply displayed informing the user of planned work during the peak hours.



Work During Rush Hour

Work During Rush Hours					
Weekday - Inbound		*Weekday - Outbound*		*Weekday - Both*	
TRUE	Morning Rush	TRUE	Morning Rush	TRUE	
TRUE	Evening Rush	TRUE	Evening Rush	TRUE	
FALSE	Morning Rush	FALSE	Morning Rush	TRUE	
FALSE	Evening Rush	FALSE	Evening Rush	TRUE	
Sunday - Inbound		*Sunday - Outbound*		*Sunday - Both*	
FALSE	Sunday Afternoon	FALSE	Sunday Afternoon	FALSE	
FALSE		FALSE		FALSE	
Saturday - Inbound		*Saturday - Outbound*		*Saturday - Both*	
FALSE	Saturday Afternoon	FALSE	Saturday Afternoon	FALSE	
FALSE		FALSE		FALSE	

Days with Work During the Peak Hours							
Inbound							
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		Monday					
Outbound							
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		Monday					

Inbound	Outbound
Monday	Monday

Figure 7-16: Work During Rush Hours Section of Hourly Distribution Worksheet.

7.1.5.5 Summary

The **HOURLY DISTRIBUTION** worksheet is the location where the AADT is divided among all days of the week and hours of the day. These values are used for two purposes. The first is to determine the numbers of vehicles that are affected by the work zone. The second is to determine if the facilities can manage the estimated traffic, or if the demand may exceed the capacity, thus resulting in congestion and queuing. Messages are displayed in the **DUCK** worksheet if the demand exceeds the capacity and if work is performed during the peak hours of the day.

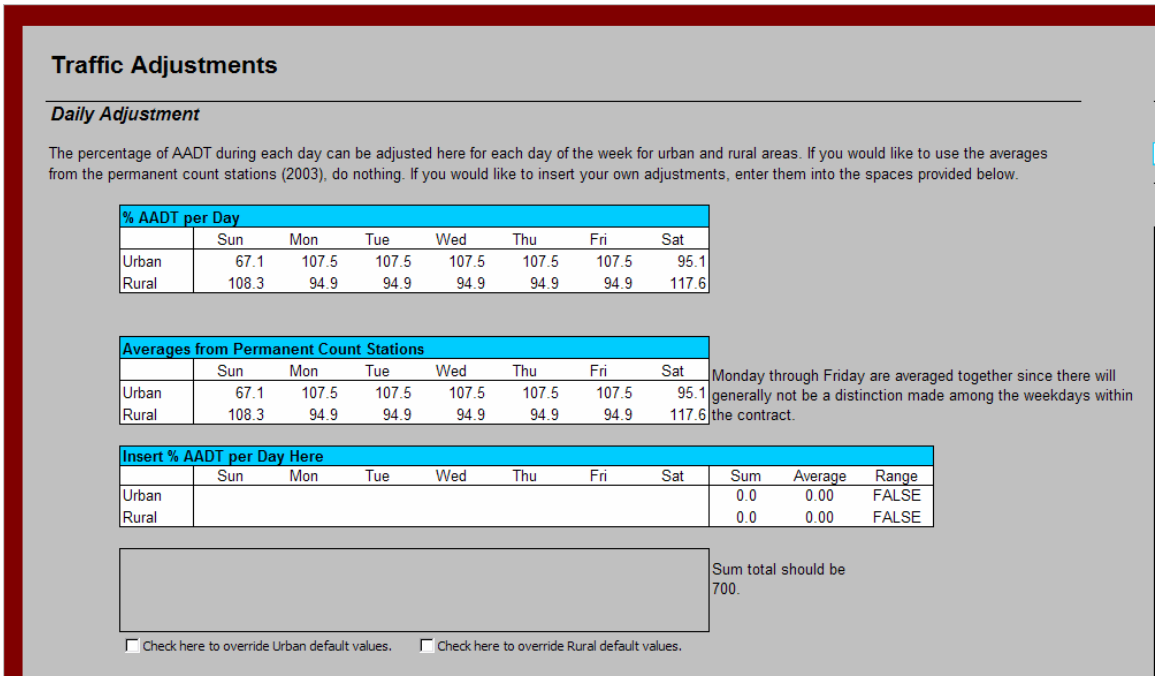
7.1.6 Traffic Adjustments

The **TRAFFIC ADJUSTMENTS** worksheet is the location set apart for adjusting the distribution of the AADT among the days of the week and for each hour of the day.

7.1.6.1 Daily Adjustment

The data for the distribution of the AADT come from UDOT's permanent count stations in 2003 and can be found at the bottom of the worksheet. This portion of the worksheet is not illustrated through a figure due to the large size of the table. Each station, assigned as a rural or urban area, shows the percentage of AADT traveling during each day of the week. Because the AADT is an annual average, it is expected that average daily volumes on some days will be higher and some lower than the AADT. The values for the weekdays are averaged together because rarely do contracts distinguish among the different weekdays.

There are three tables near the top of the worksheet in the **Daily Adjustment** section named ***% AADT per Day***, ***Averages from Permanent Count Stations***, and ***Insert % AADT per Day Here***. These tables are shown in Figure 7-17. The first table, ***% AADT per Day***, displays the values that are used in the tables on the **HOURLY DISTRIBUTION** worksheet. The second table, ***Average from Permanent Count Stations***, displays the default values obtained using the average values from the permanent count stations. These values cannot be changed.



Traffic Adjustments

Daily Adjustment

The percentage of AADT during each day can be adjusted here for each day of the week for urban and rural areas. If you would like to use the averages from the permanent count stations (2003), do nothing. If you would like to insert your own adjustments, enter them into the spaces provided below.

% AADT per Day	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Urban	67.1	107.5	107.5	107.5	107.5	107.5	95.1
Rural	108.3	94.9	94.9	94.9	94.9	94.9	117.6

Averages from Permanent Count Stations	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Urban	67.1	107.5	107.5	107.5	107.5	107.5	95.1
Rural	108.3	94.9	94.9	94.9	94.9	94.9	117.6

Monday through Friday are averaged together since there will generally not be a distinction made among the weekdays within the contract.

Insert % AADT per Day Here	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sum	Average	Range
Urban								0.0	0.00	FALSE
Rural								0.0	0.00	FALSE

Sum total should be 700.

☐ Check here to override Urban default values. ☐ Check here to override Rural default values.

Figure 7-17: Daily Adjustment Section of the Traffic Adjustments Worksheet.

The final table, ***Insert % AADT per Day Here***, is where values may be entered to change the daily distribution of AADT. There are some checks performed before the entered values will be used by the program. The first is to ensure that all seven days have a value. The second is to ensure that the sum of the AADT daily distributions is 700, meaning that the average is 100. If there is a value for all seven days and the sum is 700 or the average is 100, then the values for each day will automatically be entered into the first table for use in the **HOURLY DISTRIBUTION** worksheet. If the checks are not satisfied, then the values will not automatically be entered into the first table for use; the default values will be used instead. The way to override the defaults even if the average does not equal 100 is by checking the box found below this table for the corresponding Urban or Rural set of values, although each day must still have a value entered. The box found below the final table is the location where messages may be shown if all seven

days have a value, but the average does not equal 100. Care must be taken when entering in new values because there is no check to ensure the reasonableness of the values entered.

7.1.6.2 Hourly Adjustment

The first line of the **Hourly Adjustment** section shows the facility being closed. There are two subsections here for the weekday and weekend values. Both are similar, so only the weekday portion is described here. Figure 7-18 shows the **Hourly Adjustment** section.

There are three tables, ***Hourly Adjustments***, ***Default Values***, and ***Insert Hourly % Here***. These are similar to those found in the **Daily Adjustment** section. The first, ***Hourly Adjustments***, displays those values used in the program to distribute the daily traffic throughout the hours of the day. The second table contains the default values that are determined in tables farther below these tables, next to the permanent count station data, and shown in Figure 7-19.

Hourly Adjustment

Urban Freeway

Weekday

Hourly Adjustments		
	In	Out
0:00	0.28	0.38
1:00	0.16	0.21
2:00	0.13	0.11
3:00	0.15	0.09
4:00	0.30	0.09
5:00	1.08	0.23
6:00	3.22	1.04
7:00	4.59	2.24
8:00	3.95	2.94
9:00	2.91	2.88
10:00	2.59	2.59
11:00	2.59	2.68
12:00	2.66	2.90
13:00	2.67	3.01
14:00	2.82	3.24
15:00	3.00	3.61
16:00	3.48	4.30
17:00	3.56	4.78
18:00	2.99	4.41
19:00	2.03	3.05
20:00	1.54	2.17
21:00	1.43	1.88
22:00	0.96	1.01
23:00	0.55	0.65

Default Values		
	In	Out
0:00	0.28	0.38
1:00	0.16	0.21
2:00	0.13	0.11
3:00	0.15	0.09
4:00	0.30	0.09
5:00	1.08	0.23
6:00	3.22	1.04
7:00	4.59	2.24
8:00	3.95	2.94
9:00	2.91	2.88
10:00	2.59	2.59
11:00	2.59	2.68
12:00	2.66	2.90
13:00	2.67	3.01
14:00	2.82	3.24
15:00	3.00	3.61
16:00	3.48	4.30
17:00	3.56	4.78
18:00	2.99	4.41
19:00	2.03	3.05
20:00	1.54	2.17
21:00	1.43	1.88
22:00	0.96	1.01
23:00	0.55	0.65
Total	49.6	50.4
Total Both Directions		100

Insert Hourly % Here		
	In	Out
0:00		
1:00		
2:00		
3:00		
4:00		
5:00		
6:00		
7:00		
8:00		
9:00		
10:00		
11:00		
12:00		
13:00		
14:00		
15:00		
16:00		
17:00		
18:00		
19:00		
20:00		
21:00		
22:00		
23:00		
Total	0.0	0.0
Total Both Directions		0.0
Range	FALSE	FALSE

Sum total should be between 99.5 and 100.5.

☐ Check here to override default values.

Figure 7-18: Hourly Adjustment Section of the Traffic Adjustments Worksheet.

		Freeway											
		Urban				Rural							
		Weekday		*Weekend*		*Weekday*		*Weekend*		Default Weekday Values		Default Weekend Values	
		In	Out	In	Out	In	Out	In	Out				
1	0:00	0.0028	0.0038	0.0067	0.0080	0.0082	0.0077	0.0090	0.0068	0.28	0.38	0.67	0.80
2	1:00	0.0016	0.0021	0.0046	0.0048	0.0072	0.0059	0.0076	0.0046	0.16	0.21	0.46	0.48
3	2:00	0.0013	0.0011	0.0025	0.0021	0.0069	0.0058	0.0057	0.0047	0.13	0.11	0.25	0.21
4	3:00	0.0015	0.0009	0.0022	0.0017	0.0072	0.0060	0.0058	0.0038	0.15	0.09	0.22	0.17
5	4:00	0.0030	0.0009	0.0022	0.0011	0.0085	0.0059	0.0056	0.0036	0.30	0.09	0.22	0.11
6	5:00	0.0108	0.0023	0.0046	0.0010	0.0112	0.0085	0.0080	0.0056	1.08	0.23	0.46	0.10
7	6:00	0.0322	0.0104	0.0088	0.0031	0.0167	0.0115	0.0080	0.0111	3.22	1.04	0.88	0.31
8	7:00	0.0459	0.0224	0.0158	0.0123	0.0206	0.0149	0.0140	0.0154	4.59	2.24	1.58	1.23
9	8:00	0.0395	0.0294	0.0230	0.0194	0.0263	0.0192	0.0207	0.0236	3.95	2.94	2.30	1.94
10	9:00	0.0291	0.0288	0.0264	0.0241	0.0296	0.0238	0.0248	0.0279	2.91	2.88	2.64	2.41
11	10:00	0.0259	0.0259	0.0290	0.0280	0.0303	0.0273	0.0309	0.0350	2.59	2.59	2.90	2.80
12	11:00	0.0259	0.0268	0.0323	0.0343	0.0309	0.0290	0.0316	0.0382	2.59	2.68	3.23	3.43
13	12:00	0.0266	0.0290	0.0398	0.0378	0.0307	0.0301	0.0329	0.0314	2.66	2.90	3.98	3.78
14	13:00	0.0267	0.0301	0.0369	0.0378	0.0319	0.0318	0.0332	0.0340	2.67	3.01	3.69	3.78
15	14:00	0.0282	0.0324	0.0335	0.0377	0.0328	0.0344	0.0340	0.0291	2.82	3.24	3.35	3.77
16	15:00	0.0300	0.0361	0.0349	0.0381	0.0325	0.0355	0.0373	0.0318	3.00	3.61	3.49	3.81
17	16:00	0.0348	0.0430	0.0363	0.0477	0.0348	0.0369	0.0402	0.0318	3.48	4.30	3.63	4.77
18	17:00	0.0356	0.0478	0.0365	0.0405	0.0333	0.0368	0.0378	0.0338	3.56	4.78	3.65	4.05
19	18:00	0.0299	0.0441	0.0378	0.0369	0.0281	0.0302	0.0351	0.0279	2.99	4.41	3.78	3.69
20	19:00	0.0203	0.0305	0.0294	0.0306	0.0223	0.0255	0.0297	0.0189	2.03	3.05	2.94	3.06
21	20:00	0.0154	0.0217	0.0220	0.0164	0.0188	0.0209	0.0223	0.0218	1.54	2.17	2.20	1.64
22	21:00	0.0143	0.0188	0.0207	0.0098	0.0161	0.0176	0.0206	0.0151	1.43	1.88	2.07	0.98
23	22:00	0.0096	0.0101	0.0147	0.0081	0.0126	0.0152	0.0145	0.0142	0.96	1.01	1.47	0.81
24	23:00	0.0055	0.0065	0.0101	0.0092	0.0095	0.0125	0.0093	0.0115	0.55	0.65	1.01	0.92

Figure 7-19: Default Values for the Hourly Distribution of Traffic on the Traffic Adjustments Worksheet.

These tables display the values for various combinations of facilities according to the inbound and outbound directions, weekday and weekend, urban and rural, and freeway and arterial. Another similar table is provided for arterials, but is not shown here. These values were compiled by Michael Kaczorowski at UDOT. Depending on the type of facility containing the work zone, as determined on the **DUCK** worksheet, the proper set of hourly distribution values are displayed in the second table as the default values.

The third table, ***Insert Hourly % Here***, is where new values may be entered for use. Like the **Daily Adjustment**, there are certain checks performed before the entered values will be automatically used in the program. The first is to ensure that each hour has a value. The next check is to guarantee that the total for both directions equals 100. The split between the inbound and outbound directions is not considered in the check. There is also a checkbox for each of the weekday and weekend tables to override the default values and use those entered, even if they do not sum to exactly 100. There must still be a value for each hour for both the inbound and outbound directions. Like the **Daily Adjustment** section, there is no check to ensure reasonableness. This must be done be the user, external to the program.

7.1.6.3 Summary

The **TRAFFIC ADJUSTMENTS** worksheet is used to adjust the distribution of the AADT for each day of the week and to adjust the distribution of the daily traffic throughout the hours of the day. Although default values are provided, adjustments can be made.

7.1.7 Hourly Costs

The **COSTS** worksheet calculates the total user costs by using the value of time, cost of fuel, fuel efficiency, the lost time, and the vehicles per hour that are calculated on the **Mainline / Work Zone** section of the **HOURLY DISTRIBUTION** worksheet.

7.1.7.1 Background Information

The first section, **Background Information**, shown in Figure 7-20, contains various data points needed for the calculations. Some of these data tables are taken from the **COLLECTION** worksheet, including the ***Days and Hours***, ***Lost Time***, ***Direction and Type of Closure***, ***% Trucks***, and ***Speed*** tables. The other tables, ***Value of Time***, ***Cost of Fuel***, ***Fuel Efficiency***, and ***Fuel Cost***, relate to the actual monetary amount used in the calculations.

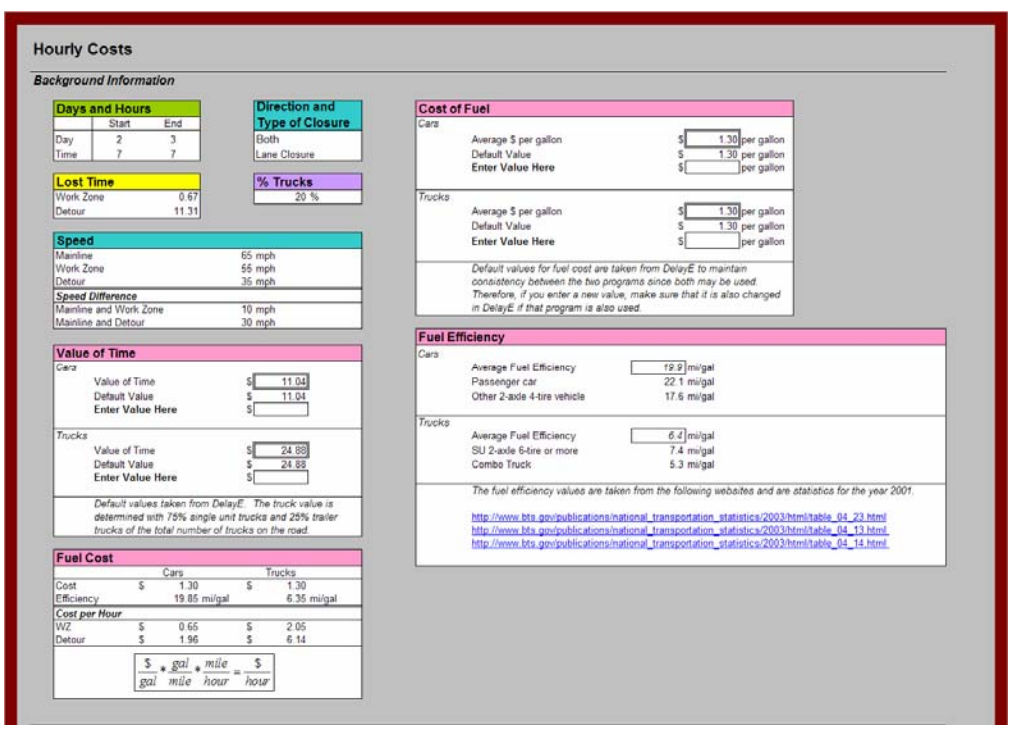


Figure 7-20: Background Information Section of the Costs Worksheet.

The ***Value of Time*** table contains the dollar figure for the value of one hour of time. The default values are from DelayE for consistency between the two programs. Both the *Cars* and *Trucks* portions of this table are similar, so only the Cars portion is described. The first line is the *Value of Time* that will be used in the program. This value will be set at the default value if the final line, labeled *Enter Value Here*, has no value, or a value of zero is entered. This final line is where the value can be changed. A non-negative or non-zero value entered here will be sent to the first line to be used in the total user cost calculations.

The second table, ***Fuel Cost***, contains values from the other related tables, ***Cost of Fuel*** and ***Fuel Efficiency***. The cost per hour for cars and trucks is in dollars per hour and determined using Equation 7-3.

$$HourlyCost = \frac{FuelCost}{FuelEfficiency} * SpeedDif \qquad \textbf{(7-3)}$$

where,

HourlyCost = vehicle cost per hour ($/hour),

FuelCost = cost per fuel ($/gallon),

FuelEfficiency = average fuel efficiency of vehicles (miles/gallon), and

SpeedDif = difference in speed between the normal flow and the speed limit in the work zone or detour route (miles/hour).

As can be seen in the **Fuel Cost** table, the cost per hour is given for cars and trucks in both the work zone and detour. The cost of fuel can be changed in the ***Cost of***

Fuel table, which is configured similar to that of the ***Value of Time*** table. The default values are from DelayE for consistency between the two programs. Both the *Cars* and *Trucks* portions of this table are similar, so only the Cars portion is described. The first line is the average cost per gallon that will be used in the program. This value will be set at the default value if there is no value or a value of zero entered on the final line which is labeled *Enter Value Here*. This final line is where the value can be changed. Entering a value here, if not zero or negative, will send the value to the first line, where it is used in the total user cost calculations.

The ***Fuel Efficiency*** table displays values gathered from the Bureau of Transportation Statistics for 2003. The average fuel efficiency for autos is taken from the passenger car and other two-axle, four-tire vehicles. The fuel efficiency for trucks is the average of the single-unit two-axle six-tire or more truck and the combination truck.

7.1.7.2 Calculations

In the **Calculations** section, the first table, ***Traffic Volumes***, shown in Figure 7-21, displays the number of vehicles affected by a closure for the inbound and outbound directions. These values are taken from the **HOURLY DISTRIBUTION** worksheet and are compiled into one table from the five separate tables in the **Mainline/Work Zone** section of the **HOURLY DISTRIBUTION** table.

Calculations

Traffic Volumes

		Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
		In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
1	0:00	0	0	0	0	355	484	0	0	0	0	0	0	0	0
2	1:00	0	0	0	0	206	265	0	0	0	0	0	0	0	0
3	2:00	0	0	0	0	161	135	0	0	0	0	0	0	0	0
4	3:00	0	0	0	0	187	110	0	0	0	0	0	0	0	0
5	4:00	0	0	0	0	387	116	0	0	0	0	0	0	0	0
6	5:00	0	0	0	0	1,387	297	0	0	0	0	0	0	0	0
7	6:00	0	0	4,148	1,335	0	0	0	0	0	0	0	0	0	0
8	7:00	0	0	5,923	2,884	0	0	0	0	0	0	0	0	0	0
9	8:00	0	0	5,097	3,787	0	0	0	0	0	0	0	0	0	0
10	9:00	0	0	3,748	3,710	0	0	0	0	0	0	0	0	0	0
11	10:00	0	0	3,342	3,336	0	0	0	0	0	0	0	0	0	0
12	11:00	0	0	3,342	3,458	0	0	0	0	0	0	0	0	0	0
13	12:00	0	0	3,432	3,736	0	0	0	0	0	0	0	0	0	0
14	13:00	0	0	3,439	3,877	0	0	0	0	0	0	0	0	0	0
15	14:00	0	0	3,639	4,181	0	0	0	0	0	0	0	0	0	0
16	15:00	0	0	3,865	4,658	0	0	0	0	0	0	0	0	0	0
17	16:00	0	0	4,490	5,548	0	0	0	0	0	0	0	0	0	0
18	17:00	0	0	4,594	6,168	0	0	0	0	0	0	0	0	0	0
19	18:00	0	0	3,858	5,684	0	0	0	0	0	0	0	0	0	0
20	19:00	0	0	2,613	3,936	0	0	0	0	0	0	0	0	0	0
21	20:00	0	0	1,981	2,794	0	0	0	0	0	0	0	0	0	0
22	21:00	0	0	1,839	2,426	0	0	0	0	0	0	0	0	0	0
23	22:00	0	0	1,239	1,303	0	0	0	0	0	0	0	0	0	0
24	23:00	0	0	710	839	0	0	0	0	0	0	0	0	0	0
		Total Vehicles		129,047											
		Cars		103,237											
		Trucks		25,809											

Figure 7-21: Traffic Volumes Table on the Costs Worksheet.

The second table, ***Hourly Lost Time***, shown in Figure 7-22, displays the total lost hours for each hour of the day during the closure. Equation 7-4 shows how the hourly lost time is calculated.

Hourly Lost Time

		Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
		In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
1	0:00	0.0	0.0	0.0	0.0	4.0	5.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	1:00	0.0	0.0	0.0	0.0	2.3	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	2:00	0.0	0.0	0.0	0.0	1.8	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	3:00	0.0	0.0	0.0	0.0	2.1	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	4:00	0.0	0.0	0.0	0.0	4.3	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	5:00	0.0	0.0	0.0	0.0	15.5	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	6:00	0.0	0.0	46.4	14.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	7:00	0.0	0.0	66.3	32.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	8:00	0.0	0.0	57.0	42.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	9:00	0.0	0.0	41.9	41.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	10:00	0.0	0.0	37.4	37.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	11:00	0.0	0.0	37.4	38.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	12:00	0.0	0.0	38.4	41.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	13:00	0.0	0.0	38.5	43.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	14:00	0.0	0.0	40.7	46.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	15:00	0.0	0.0	43.2	52.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	16:00	0.0	0.0	50.2	62.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	17:00	0.0	0.0	51.4	69.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	18:00	0.0	0.0	43.2	63.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	19:00	0.0	0.0	29.2	44.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	20:00	0.0	0.0	22.2	31.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	21:00	0.0	0.0	20.6	27.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	22:00	0.0	0.0	13.9	14.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	23:00	0.0	0.0	7.9	9.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Total Lost Hours		1,443.9 hours											
		Cars		1,155.1 hours											
		Trucks		288.8 hours											

Figure 7-22: Hourly Lost Time Table on the Costs Worksheet.

$$HLT = TrafVol * \frac{LostTime}{60} \qquad \textbf{(7-4)}$$

where,

HLT = hourly lost time (hours),

TrafVol = traffic volumes (vehicles), and

LostTime = lost time due to delay for each vehicle (minutes/vehicle).

The next table, ***Hourly Lost Time Cost***, shown in Figure 7-23, multiplies the ***Hourly Lost Time*** by the value of time. The percentage and value of time for both cars and trucks is taken into account in this calculation. Equation 7-5 shows how the ***Hourly Lost Time Cost*** table calculates the values for each hour.

Hourly Lost Time Cost

		Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
		In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
1	0:00	0.00	0.00	0.00	0.00	54.82	74.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1:00	0.00	0.00	0.00	0.00	31.90	40.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	2:00	0.00	0.00	0.00	0.00	24.92	20.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	3:00	0.00	0.00	0.00	0.00	28.91	16.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	4:00	0.00	0.00	0.00	0.00	59.81	17.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	5:00	0.00	0.00	0.00	0.00	214.30	45.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	6:00	0.00	0.00	640.91	206.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	7:00	0.00	0.00	915.02	445.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	8:00	0.00	0.00	787.43	585.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	9:00	0.00	0.00	579.11	573.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	10:00	0.00	0.00	516.32	515.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	11:00	0.00	0.00	516.32	534.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	12:00	0.00	0.00	530.27	577.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	13:00	0.00	0.00	531.27	599.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	14:00	0.00	0.00	562.17	645.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	15:00	0.00	0.00	597.06	719.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	16:00	0.00	0.00	693.74	857.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	17:00	0.00	0.00	709.69	952.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	18:00	0.00	0.00	596.06	878.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	19:00	0.00	0.00	403.68	608.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	20:00	0.00	0.00	306.00	431.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	21:00	0.00	0.00	284.07	374.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	22:00	0.00	0.00	191.38	201.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	23:00	0.00	0.00	109.64	129.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Total	$		19,937.05										
		Cars	$		12,752.32										
		Trucks	$		7,184.73										

Figure 7-23: Hourly Lost Time Cost Table on the Costs Worksheet.

$$HLTC = (\%Cars * HLT * VOT_{Cars}) + (\%Trucks * HLT * VOT_{Trucks}) \quad \textbf{(7-5)}$$

where,

$HLTC$ = hourly lost time cost ($),

HLT = hourly lost time (hours),

VOT_{Cars} = value of time for cars ($/hour), and

VOT_{Trucks} = value of time for trucks ($/hour).

The next table, ***Hourly Fuel Cost***, displayed in Figure 7-24, takes into account the cost of the fuel for the time lost due to the lane closure. Equation 7-6 shows how the hourly fuel cost values are determined.

Hourly Fuel Cost

		Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
		In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
1	0:00	0.00	0.00	0.00	0.00	3.71	5.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1:00	0.00	0.00	0.00	0.00	2.16	2.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	2:00	0.00	0.00	0.00	0.00	1.68	1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	3:00	0.00	0.00	0.00	0.00	1.95	1.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	4:00	0.00	0.00	0.00	0.00	4.04	1.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	5:00	0.00	0.00	0.00	0.00	14.49	3.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	6:00	0.00	0.00	43.32	13.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	7:00	0.00	0.00	61.85	30.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	8:00	0.00	0.00	53.23	39.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	9:00	0.00	0.00	39.15	38.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	10:00	0.00	0.00	34.90	34.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	11:00	0.00	0.00	34.90	36.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	12:00	0.00	0.00	35.84	39.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	13:00	0.00	0.00	35.91	40.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	14:00	0.00	0.00	38.00	43.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	15:00	0.00	0.00	40.36	48.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	16:00	0.00	0.00	46.89	57.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	17:00	0.00	0.00	47.97	64.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	18:00	0.00	0.00	40.29	59.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	19:00	0.00	0.00	27.29	41.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	20:00	0.00	0.00	20.68	29.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	21:00	0.00	0.00	19.20	25.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	22:00	0.00	0.00	12.94	13.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	23:00	0.00	0.00	7.41	8.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		Total	$		1,347.68										
		Cars	$		756.49										
		Trucks	$		591.19										

Figure 7-24: Hourly Fuel Cost on the Costs Worksheet.

$$HFC = (\%Cars * HLT * FC_{Cars}) + (\%Trucks * HLT * FC_{Trucks}) \quad \textbf{(7-6)}$$

where,

HFC = hourly fuel cost ($),

HLT = hourly lost time (hours),

FC_{Cars} = fuel cost for cars ($/hour), and

FC_{Trucks} = fuel cost for trucks ($/hour).

The final two tables, presented in Figure 7-25, are both named ***Total User Delay Cost***. The first is similar to the previous tables and shows each hour of the week individually. The second table is a summary of the total costs from each table. The values in the first table are determined simply by adding the values of the ***Hourly Lost Time Cost*** and ***Hourly Fuel Cost*** tables together as seen in Equation 7-7.

Total User Delay Cost

Hourly Lost Time Cost + Fuel Cost

		Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
		In	*Out*	*In*	*Out*	*In*	*Out*	*In*	*Out*	*In*	*Out*	*In*	*Out*	*In*	*Out*
1	0:00	0.00	0.00	0.00	0.00	58.53	79.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1:00	0.00	0.00	0.00	0.00	34.05	43.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	2:00	0.00	0.00	0.00	0.00	26.60	22.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	3:00	0.00	0.00	0.00	0.00	30.86	18.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	4:00	0.00	0.00	0.00	0.00	63.85	19.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	5:00	0.00	0.00	0.00	0.00	228.79	48.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	6:00	0.00	0.00	684.24	220.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	7:00	0.00	0.00	976.87	475.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	8:00	0.00	0.00	840.66	624.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	9:00	0.00	0.00	618.26	611.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	10:00	0.00	0.00	551.22	550.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	11:00	0.00	0.00	551.22	570.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	12:00	0.00	0.00	566.12	616.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	13:00	0.00	0.00	567.18	639.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	14:00	0.00	0.00	600.17	689.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	15:00	0.00	0.00	637.41	768.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	16:00	0.00	0.00	740.63	915.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	17:00	0.00	0.00	757.66	1,017.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	18:00	0.00	0.00	636.35	937.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	19:00	0.00	0.00	430.97	649.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	20:00	0.00	0.00	326.69	460.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	21:00	0.00	0.00	303.28	400.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	22:00	0.00	0.00	204.31	214.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	23:00	0.00	0.00	117.05	138.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total		$		21,284.74										
	Cars		$		13,508.81										
	Trucks		$		7,775.93										

Total User Delay Cost

	Cars	*Trucks*
Lost Time Cost	12,752	7,185
Fuel Cost	756	591
Total	13,509	7,776
Grand Total	$ ***21,285***	

Figure 7-25: Total User Delay Cost Tables on the Costs Worksheet.

$$TUDC = HLTC + HFC \tag{7-7}$$

where,

$TUDC$ = total user delay cost ($),

$HLTC$ = hourly lost time cost ($), and

HFC = hourly fuel cost ($).

The end result is the *Total User Delay Cost*, which is the value that may be used for incentives. This value is sent to the line labeled ***Total Delay Cost for Analysis Period*** in the **Results** section of the **DUCK** worksheet.

7.1.7.3 Summary

The **COSTS** worksheet displays the steps for determining the individual costs involved with the total user cost. The value of time and fuel costs may be adjusted as needed, but should be reasonable and justifiable by using research or properly published reports. The calculations are simple, straightforward, and determine the total user delay cost based upon the number of vehicles during the hours of the lane closure, the value of time, and the cost of fuel.

7.1.8 Capacity

The **CAPACITY** worksheet, shown in Figure 7-26, does not affect the outcome of the total user cost in DUCK, but is ultimately used for displaying warning messages concerning the demand and the capacity of the facilities. Thus, this worksheet may affect the final result, but only by displaying messages to use the program DelayE to determine the costs attributed to queuing delays.

Capacity

Lanes Normally Open	
Mainline - Inbound	3
Mainline - Outbound	3
Detour - Total	6

Lanes Closed in Work Zone	
Work Zone - Inbound	1
Work Zone - Outbound	1

Facility Type
Freeway

Normal Capacity	
Freeway	2,200 veh/hr
Arterial	900 veh/hr
Inbound	6,600 veh/hr
Outbound	6,600 veh/hr
Detour	5,400 veh/hr

Reduced Capacity	
Inbound	3,102 veh/hr
Outbound	3,102 veh/hr

Recommended Capacity	
Checkboxes	
TRUE	Inbound
TRUE	Outbound
TRUE	Detour
Entered Values	
0	Inbound
0	Outbound
0	Detour
All Recommended Capacity	
3,102	Inbound
3,102	Outbound
5,400	Detour

Percent Reduction

Lanes Normally Open

Lanes Closed

	1	2	3	4	5	6	7	8	9	10
0	0	0	0	0	0	0	0	0	0	0
1	100	70	53	47	44	43	40	39	38	37
2		100	80	65	58	53	50	48	46	45
3			100	80	75	65	60	57	54	52
4				100	86	77	70	66	62	58
5					100	88	79	74	69	65
6						100	90	83	77	72
7							100	92	85	79
8								100	93	86
9									100	93
10										100

This table comes from DelayE, developed by Peter Knopp.

Inbound

	3
0	0
1	53
2	80
3	100
4	0
5	0
6	0
7	0
8	0
9	0
10	0

53 %

Outbound

	3
0	0
1	53
2	80
3	100
4	0
5	0
6	0
7	0
8	0
9	0
10	0

53 %

Figure 7-26: Capacity Worksheet.

The tables near the top are similar to those found on other worksheets. The **Percent Reduction** section displays a matrix of *Lanes Normally Open* and *Lanes Closed*.

The values then in the matrix represent the percentage decrease in capacity caused by the closed lanes. A similar set of values are found in the DelayE program, from which these numbers are taken to ensure consistency. The small tables near the bottom are used simply for the program to single out the correct value using the inputs given. Using the values entered to describe the number of lanes normally open and the number of lanes closed, the bottom tables search through the matrix to find the percent reduction in the capacity. This value is then sent to the **DUCK** worksheet.

7.1.9 Printing

The final two worksheets, **PRINT** and **PRINT COSTS**, display the information from the **DUCK** and **COSTS** worksheets, respectively, in a page formatted for printing. All information fits onto one page and can be printed in black and white for ease of use.

The **PRINT** page, shown in Figure 7-27, displays the information shown in the **DUCK** worksheet and is configured in a similar fashion. The **PRINT COSTS** page, in Figure 7-28, displays the costs attributed to each hour of the week for the inbound and outbound directions. This table allows the user to see how the costs change throughout the day. The total delay cost is also shown at the bottom of the page. The peak hours of the day are highlighted in light blue on the screen and will print off in light gray on a black-and-white printer.

Project Information

Project	Project Name
Location of Work Zone	Freeway from Point A to Point B
Day and Time of Closure	Monday 6:00 to Tuesday 6:00
Number of Hours Closed	24 hours — 1 days 0 hours
Facility Type being Closed	Urban Freeway
Direction of Closure	Both Directions
Type of Closure	Lane Closure
Normal Speed	65 mph
Number of Lanes	3 Inbound
	3 Outbound

Route Description

Work Zone		
AADT	120,000	vehicles
Percentage Trucks	20	%
Number of Closed Lanes	1	Inbound
	1	Outbound
Length	4	miles
Speed	55	mph
Total Capacity	3,102	Inbound
	3,102	Outbound

Detour		
AADT	40,000	vehicles
Number of Open Lanes	6	lanes total
Total Capacity	5,400	veh/hr/lane
Detour Delay		
Measured Travel Time	15.0	min
Calculated Travel Time	13.5	min
Length	6	miles
Speed	35	mph

Traffic Signal Delay	*Number of Signals*	*Average Delay per Signal*	
	5	30	sec
	1	45	sec
	0	0	sec
Total		195	sec

Travel Time Used: *Measured* 15.0 min

Results

Days with Work During the Peak Hours
Monday

Travel Time		
Mainline	3.7	min
Work Zone	4.4	min
Detour	15.0	min
Lost Time		
Through Work Zone	0.7	min / vehicle
Through Detour	11.3	min / vehicle

Messages
Demand exceeds capacity both directions in Work Zone. Use DelayE.
Construction both directions during weekday morning peak.
Construction both directions during weekday evening peak.

	Work Zone	*Detour*
Total Number of Vehicles		
Cars	103,237	0
Trucks	25,809	0
Grand Total (vehicles)	129,047	

Total Lost Time		
Cars	1,155 hours	0 hours
Trucks	289 hours	0 hours
Grand Total (hours)	1,443.9 hours	

Delay Cost		
Cars	$	13,509
Trucks	$	7,776

Total Delay Cost for Analysis Period $ 21,285

Figure 7-27: Print Page from DUCK.

Total Hourly Costs

Project	Project Name
Location of Work Zone	Freeway from Point A to Point B

	Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
0:00	0	0	0	0	59	80	0	0	0	0	0	0	0	0
1:00	0	0	0	0	34	44	0	0	0	0	0	0	0	0
2:00	0	0	0	0	27	22	0	0	0	0	0	0	0	0
3:00	0	0	0	0	31	18	0	0	0	0	0	0	0	0
4:00	0	0	0	0	64	19	0	0	0	0	0	0	0	0
5:00	0	0	0	0	229	49	0	0	0	0	0	0	0	0
6:00	0	0	684	220	0	0	0	0	0	0	0	0	0	0
7:00	0	0	977	476	0	0	0	0	0	0	0	0	0	0
8:00	0	0	841	625	0	0	0	0	0	0	0	0	0	0
9:00	0	0	618	612	0	0	0	0	0	0	0	0	0	0
10:00	0	0	551	550	0	0	0	0	0	0	0	0	0	0
11:00	0	0	551	570	0	0	0	0	0	0	0	0	0	0
12:00	0	0	566	616	0	0	0	0	0	0	0	0	0	0
13:00	0	0	567	640	0	0	0	0	0	0	0	0	0	0
14:00	0	0	600	690	0	0	0	0	0	0	0	0	0	0
15:00	0	0	631	768	0	0	0	0	0	0	0	0	0	0
16:00	0	0	741	915	0	0	0	0	0	0	0	0	0	0
17:00	0	0	758	1,017	0	0	0	0	0	0	0	0	0	0
18:00	0	0	636	937	0	0	0	0	0	0	0	0	0	0
19:00	0	0	431	649	0	0	0	0	0	0	0	0	0	0
20:00	0	0	327	461	0	0	0	0	0	0	0	0	0	0
21:00	0	0	303	400	0	0	0	0	0	0	0	0	0	0
22:00	0	0	204	215	0	0	0	0	0	0	0	0	0	0
23:00	0	0	117	138	0	0	0	0	0	0	0	0	0	0
Total	0	0	10,110	10,500	443	232	0	0	0	0	0	0	0	0
Total	0		20,610		675		0		0		0		0	

Delay Cost		
Cars	$	13,509
Trucks	$	7,776

Total Delay Cost for Analysis Period	***$***	***21,285***

Portions of the table encircled by the double lines and shaded indicate times of the morning and evening rush on weekdays and the peak hours of the afternoon on the weekend.

Figure 7-28: Print Costs Page from DUCK.

7.1.10 Conclusions

The DUCK program has been designed to calculate the total user cost based on the reduced speed through the work zone or resulting from a detour. The details of the DUCK program have been described, showing how the many worksheets help automate some of the calculations, such as determining the number of vehicles on the facility at any hour of the week. Therefore, basic information is entered and the estimated user cost is then automatically displayed. The distribution of vehicles provided by DUCK can be used in DelayE when entering the demand for the facility during the work period. Vehicle distribution can be found on the first table of the **Mainline/Work Zone** section of the **HOURLY DISTRIBUTION** worksheet.

7.2 DelayE

DelayE is the second step for determining user costs and should be used for freeways or rural roads with few cross streets. DUCK is used to determine costs due to delay caused by slower speeds. DelayE is used to determine costs due to queuing effects from demand greater than the capacity. This section discusses the basic instructions on how to use the DelayE computer program created by Martin Knopp while working at UDOT. Figure 7-29 shows the opening screen of DelayE when loaded.

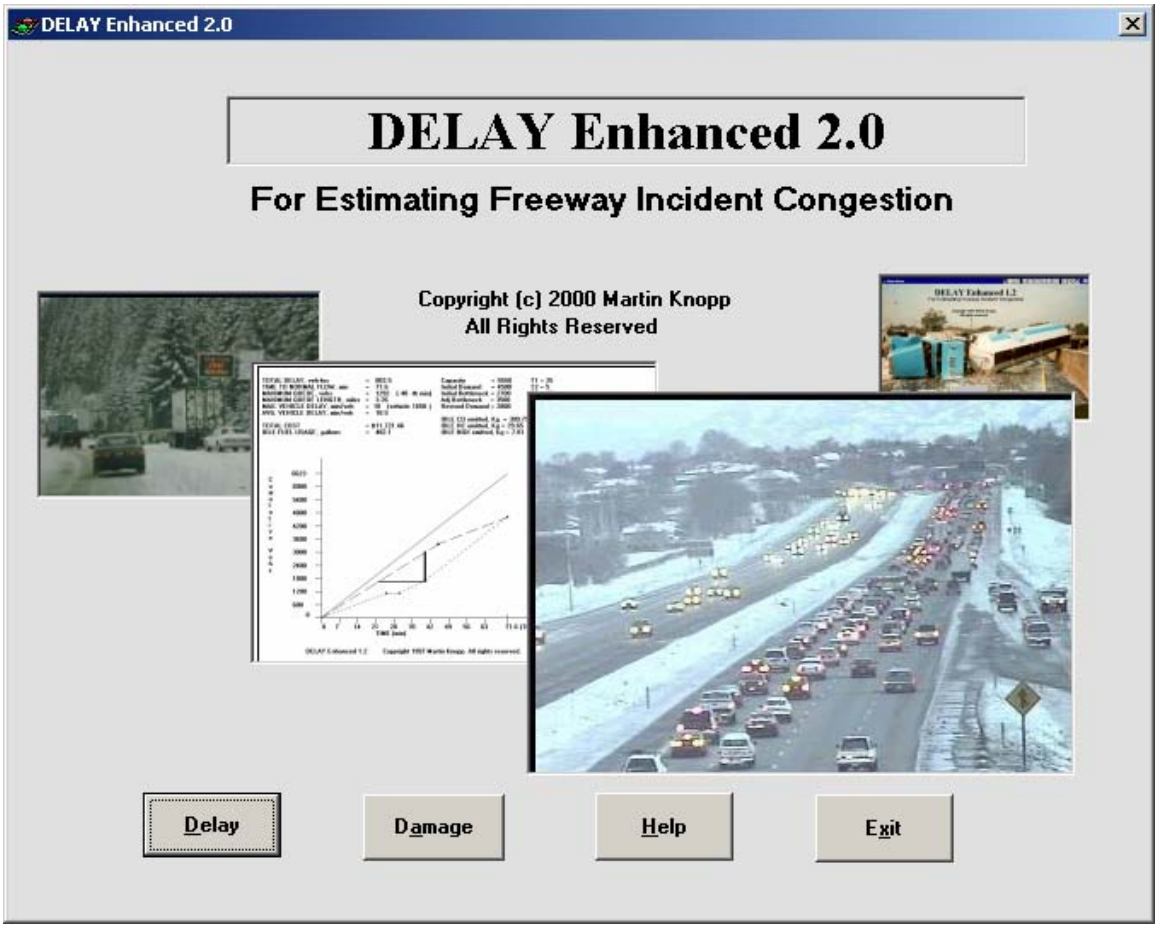


Figure 7-29: Opening Screen of DelayE.

7.2.1 Setup

Upon opening DelayE, clicking the Delay button opens the schematic diagram of a highway layout as shown in Figure 7-30.

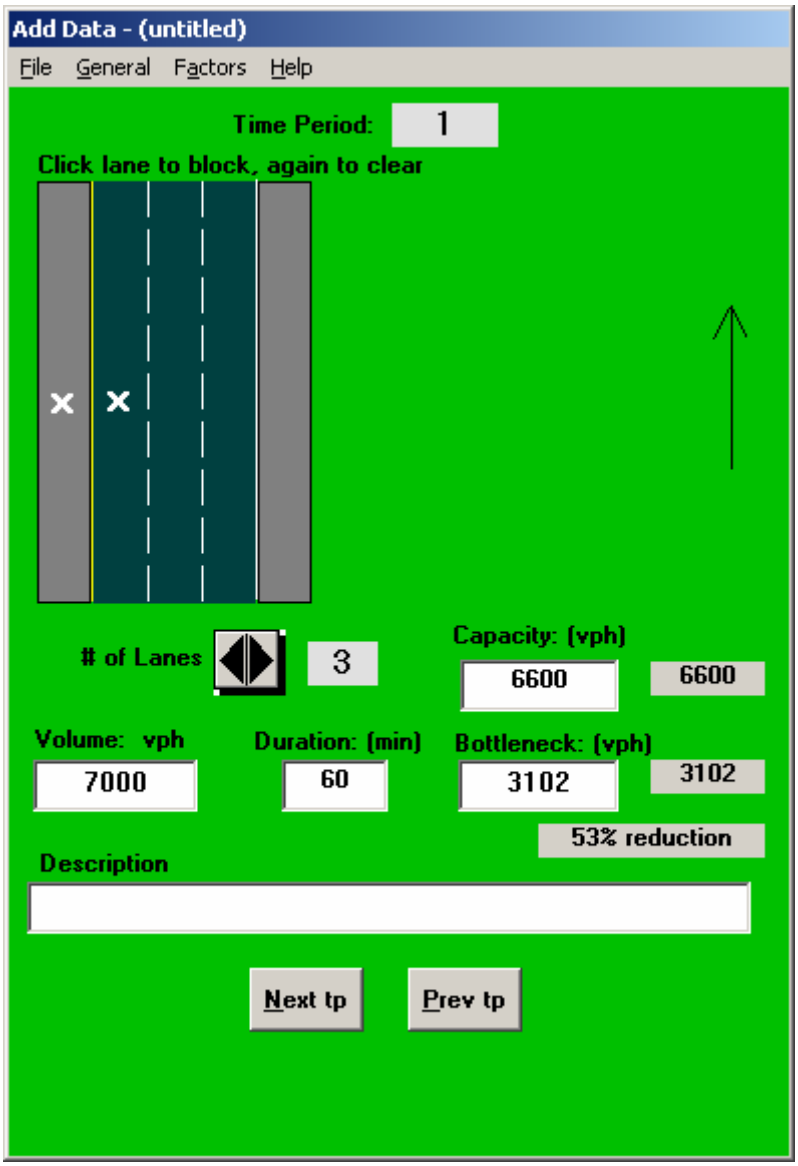


Figure 7-30: Input Screen for DelayE.

Clicking on the lanes and shoulders by the user will cause an X to appear, indicating that the lane or shoulder is closed. Clicking it again will remove the X. The arrow buttons just below the street layout will adjust the number of lanes available when no work zone exists. Towards the bottom right corner of the window, the default capacity of the roadway is shown. As more lanes are closed, the capacity displayed in the gray-shaded area decreases automatically using default values in the program. This value must be entered into the box next to it to be used in the program. By clicking on the capacity value in gray, the number will be entered into the white box for use. The user may also type in the value to use.

At the bottom left is a box in which the traffic volume demand is entered. The first time period must have a demand that is greater than the capacity; otherwise, a message appears informing the user to enter a demand greater than the capacity. Hourly traffic demand volumes may be found in the Hourly Distribution Worksheet in DUCK (see Section 7.1.5). All time periods must have the same time interval. It is recommended that 60-minute intervals be used for ease of use. Having entered the first traffic volume, the user should click the "Next tp" button to continue on to the next time period. The "tp" stands for "time period." Time periods with demand exceeding capacity may be entered. Even though the demand may be less than the capacity in the hours immediately after the final hour with a demand greater than the capacity, there may still be a queue backed up from previous hours. Therefore, demand volumes after the final volume with demand greater than the capacity may need to be entered to observe the reduction in the queue. This may be seen by observing the graph just to the right of where the data is entered into the program.

Input data critical to estimating user costs are vehicle mix, value of time, fuel cost, vehicle occupancy, etc. These values can be modified in DelayE in the AddData window. From the main menu of the AddData window, select Factors, then the Calculation option, which opens the data entry window shown in Figure 7-31 . As shown in the figure vehicle mix, value of time for different vehicle types can be entered. The values shown in Figure 7-31 are sample values. Enter appropriate values that reflect the conditions in Utah before using DelayE to compute user costs caused by queuing.

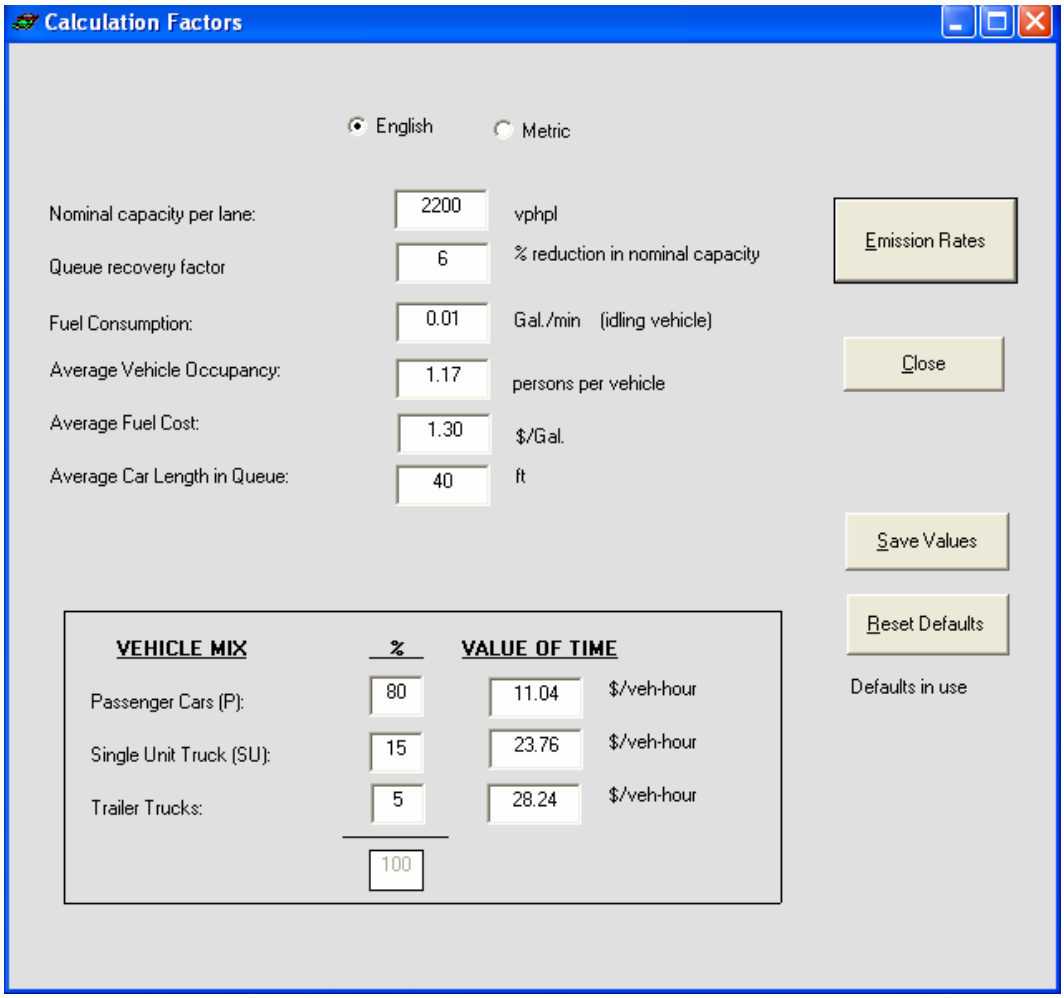


Figure 7-31: Calculation Factors Window of DelayE

7.2.2 Outputs

To run the delay calculation, the user should click on File at the top of the page and then click on Execute. Results are then displayed on a new window called "Calculation Results." From the top of this window the user can locate various sets of results by clicking on the appropriate button. These sets of data are as follows:

- Results Per Minute.
- Results Summary.
- View Input Data.
- Graph.

The total user costs are displayed in the Results Summary section. This window is shown in Figure 7-32. The results will show how long the total, average, and maximum delay will be, the queue length, and the total user cost, along with other results.

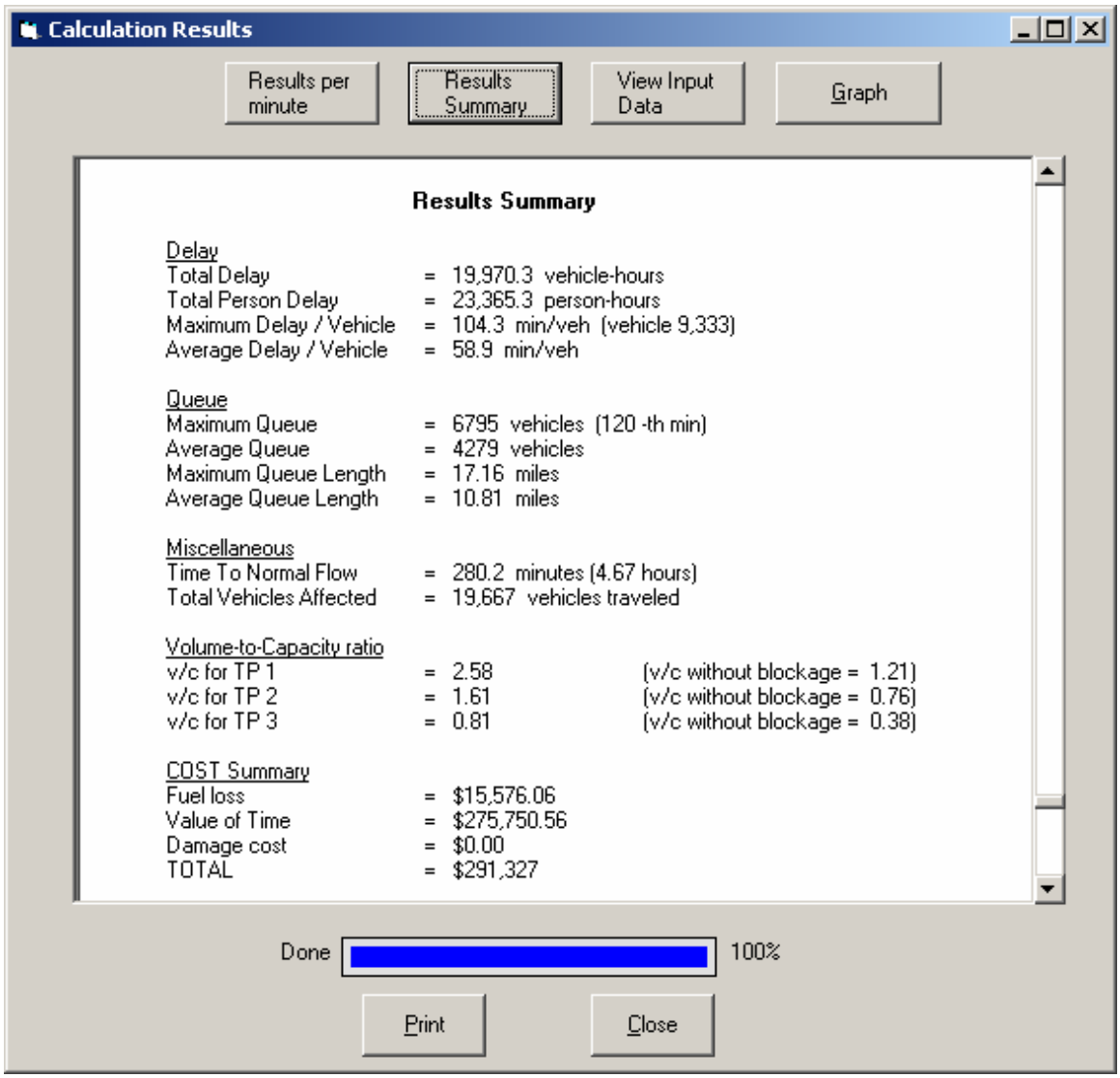


Figure 7-32: Results Summary for DelayE.

7.2.3 Conclusions

DelayE is an simple program used to determine the user costs caused by queuing effects. This program is user-friendly by way of a simple diagram of the roadway lanes and by displaying a graph illustrating the difference between demand and capacity. The results are displayed and well-explained.

7.3 Summary

DUCK and DelayE should be used by UDOT for determining an estimate of delay costs. This chapter has shown how the programs work and the results that can be garnered from each. DUCK is to be used for projects where the delay is caused by a reduction in speed while DelayE is to be used for projects where the source of delay stems from queues forming due to the demand greater than the capacity of the facility. Both programs are simple and not difficult to learn, characteristics desired by UDOT employees.

Chapter 8. Sample Calculations

This chapter shows results from a sample calculation using DUCK and DelayE. DUCK is used only to determine the costs associated with the reduced speed of vehicles traveling through the work zone. DelayE is used to determine the costs associated with the queuing effect. Therefore, the two values will not be the same; DelayE will be larger because the queuing delay results in much more lost time than a reduction in speed.

8.1 Example

The example used for this demonstration will involve a work zone set up for one day, from 06:00 Monday morning to 06:00 Tuesday morning on an urban freeway. Normally there are three open lanes in each direction with a speed limit of 65 mph. The closure will involve both directions and will be considered a lane closure because only one lane in each direction will be closed. The total AADT for both directions is 120,000, with 20 percent trucks. The length of the work zone is four miles and has a reduced speed limit of 55 mph through the work zone. These inputs can be seen in the previous chapter and are shown again in Figure 8-1 and Figure 8-2.

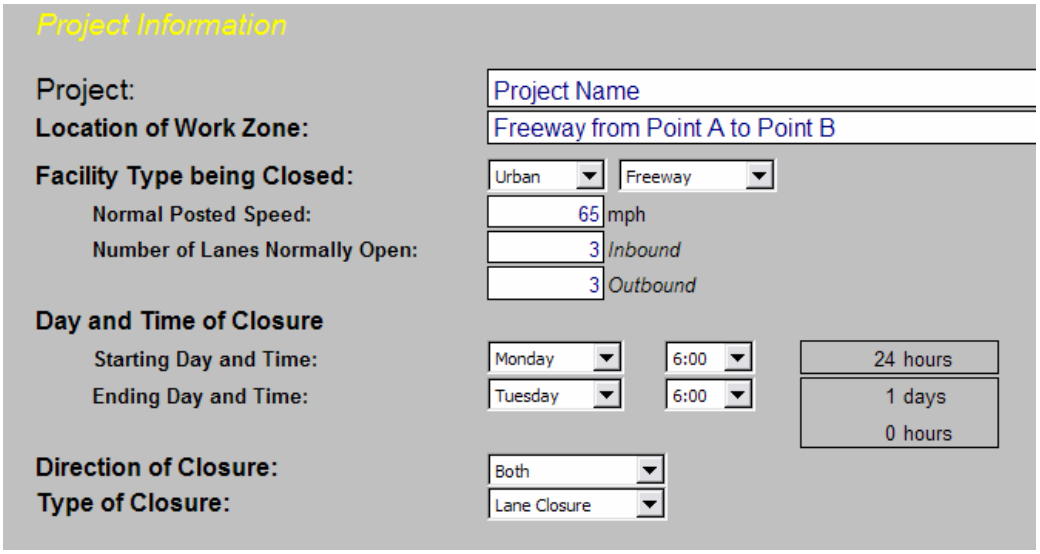


Figure 8-1: Project Information for the Example Using DUCK.

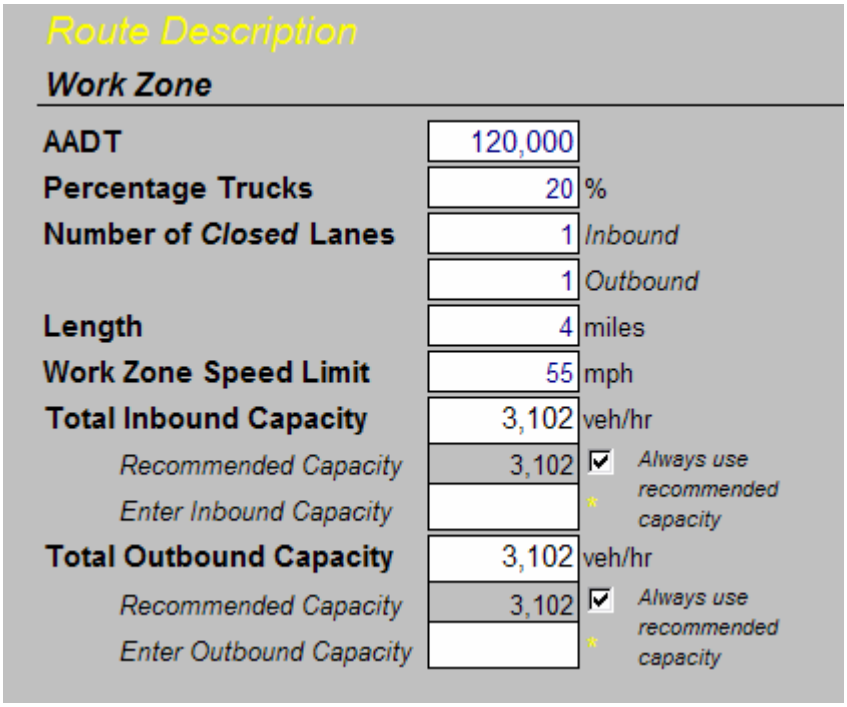
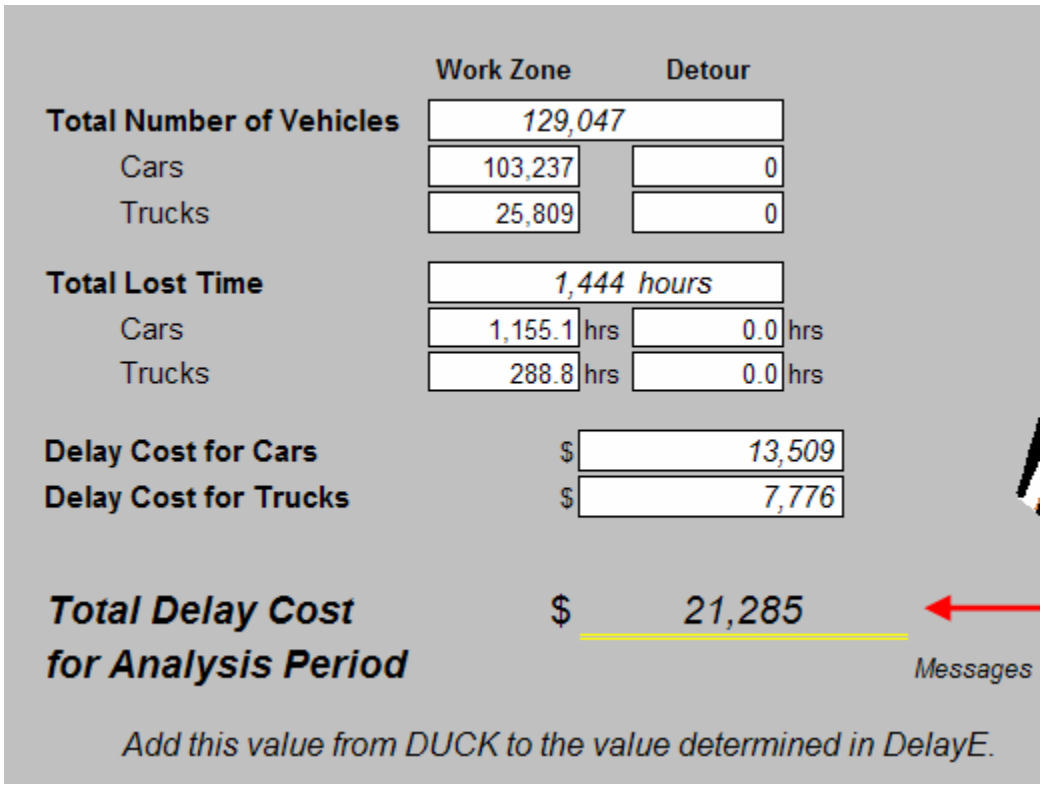


Figure 8-2: Inputs for the Example Using DUCK.

Once these values have been entered into the program, the user needs to simply scroll down to the outputs section to view the results. Figure 8-3 shows a close-up of the results.



	Work Zone	Detour
Total Number of Vehicles	129,047	
Cars	103,237	0
Trucks	25,809	0
Total Lost Time	1,444 hours	
Cars	1,155.1 hrs	0.0 hrs
Trucks	288.8 hrs	0.0 hrs
Delay Cost for Cars	$ 13,509	
Delay Cost for Trucks	$ 7,776	
Total Delay Cost for Analysis Period	$ 21,285	

Messages

Add this value from DUCK to the value determined in DelayE.

Figure 8-3: Outputs for the Example Using DUCK.

Because the demand exceeds the capacity, as shown in Figure 8-3, DelayE should be used next. Figure 8-4 shows where the hourly values for the site may be found in DUCK to use in DelayE. The user should click on the Costs tab in DUCK to see the spreadsheet with the values shown here. This table shows only the values used in the calculations for the total user cost.

Calculations

Traffic Volumes

		Sunday		Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
		In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
1	0:00	0	0	0	0	355	484	0	0	0	0	0	0	0	0
2	1:00	0	0	0	0	206	265	0	0	0	0	0	0	0	0
3	2:00	0	0	0	0	161	135	0	0	0	0	0	0	0	0
4	3:00	0	0	0	0	187	110	0	0	0	0	0	0	0	0
5	4:00	0	0	0	0	387	116	0	0	0	0	0	0	0	0
6	5:00	0	0	0	0	1,387	297	0	0	0	0	0	0	0	0
7	6:00	0	0	4,148	1,335	0	0	0	0	0	0	0	0	0	0
8	7:00	0	0	5,923	2,884	0	0	0	0	0	0	0	0	0	0
9	8:00	0	0	5,097	3,787	0	0	0	0	0	0	0	0	0	0
10	9:00	0	0	3,748	3,710	0	0	0	0	0	0	0	0	0	0
11	10:00	0	0	3,342	3,336	0	0	0	0	0	0	0	0	0	0
12	11:00	0	0	3,342	3,458	0	0	0	0	0	0	0	0	0	0
13	12:00	0	0	3,432	3,736	0	0	0	0	0	0	0	0	0	0
14	13:00	0	0	3,439	3,877	0	0	0	0	0	0	0	0	0	0
15	14:00	0	0	3,639	4,181	0	0	0	0	0	0	0	0	0	0
16	15:00	0	0	3,865	4,658	0	0	0	0	0	0	0	0	0	0
17	16:00	0	0	4,490	5,548	0	0	0	0	0	0	0	0	0	0
18	17:00	0	0	4,594	6,168	0	0	0	0	0	0	0	0	0	0
19	18:00	0	0	3,858	5,684	0	0	0	0	0	0	0	0	0	0
20	19:00	0	0	2,613	3,936	0	0	0	0	0	0	0	0	0	0
21	20:00	0	0	1,981	2,794	0	0	0	0	0	0	0	0	0	0
22	21:00	0	0	1,839	2,426	0	0	0	0	0	0	0	0	0	0
23	22:00	0	0	1,239	1,303	0	0	0	0	0	0	0	0	0	0
24	23:00	0	0	710	839	0	0	0	0	0	0	0	0	0	0
		Total Vehicles		129,047											
		Cars		103,237											
		Trucks		25,809											

DUCK | Costs | Print | Print Costs | Collection | Hourly Distribution | Traffic Adjustments | Capacity

Figure 8-4: Costs Table in DUCK.

The example for DelayE will only show a few hours on Monday morning, although the demand actually exceeds the bottleneck capacity of 3,102 vph for most of the daylight hours. Figure 8-5, Figure 8-6, and Figure 8-7 show the inputs for 06:00 to 09:00 Monday morning.

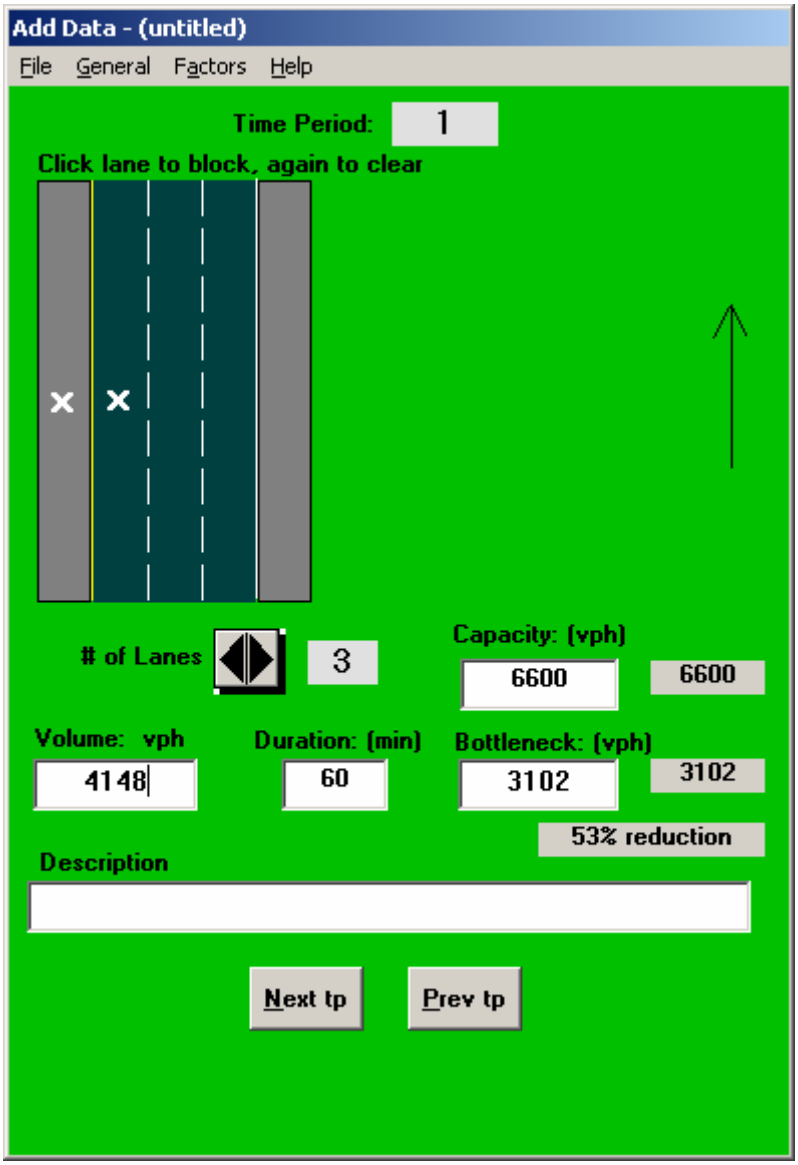


Figure 8-5: First Hour Input for the Example Using DelayE.

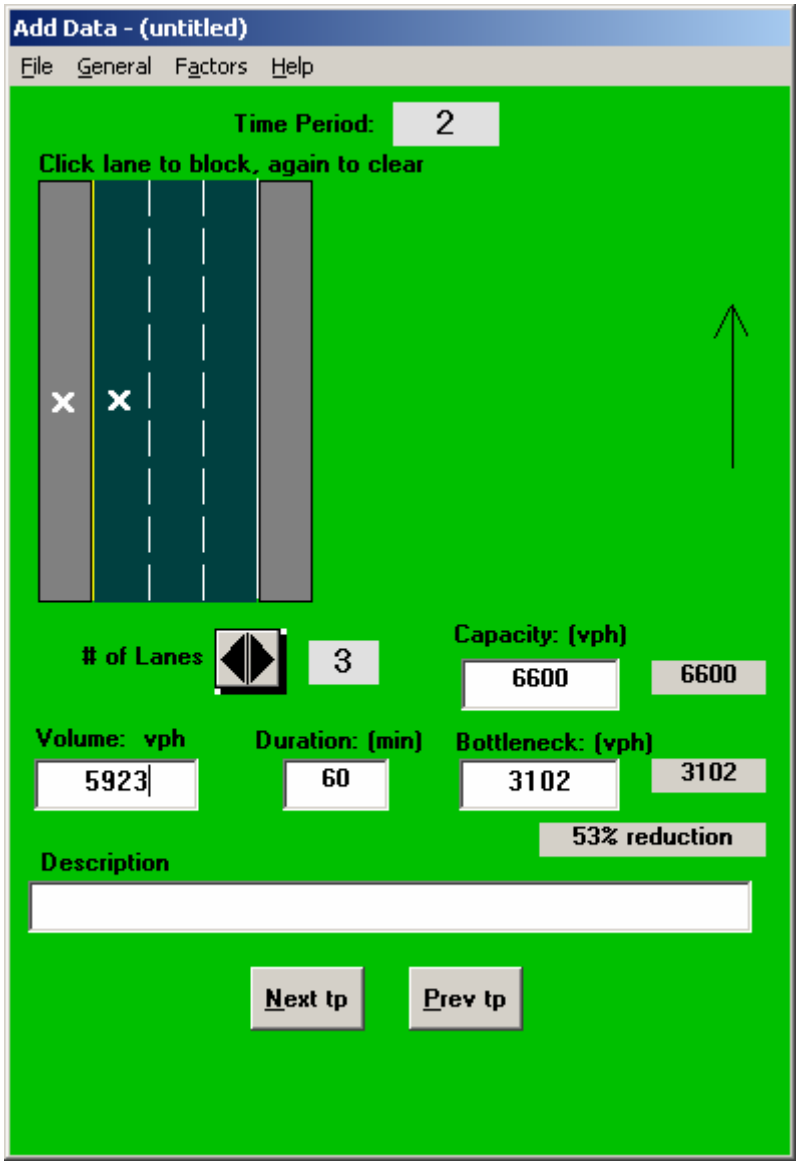


Figure 8-6: Second Hour Input for the Example Using DelayE.

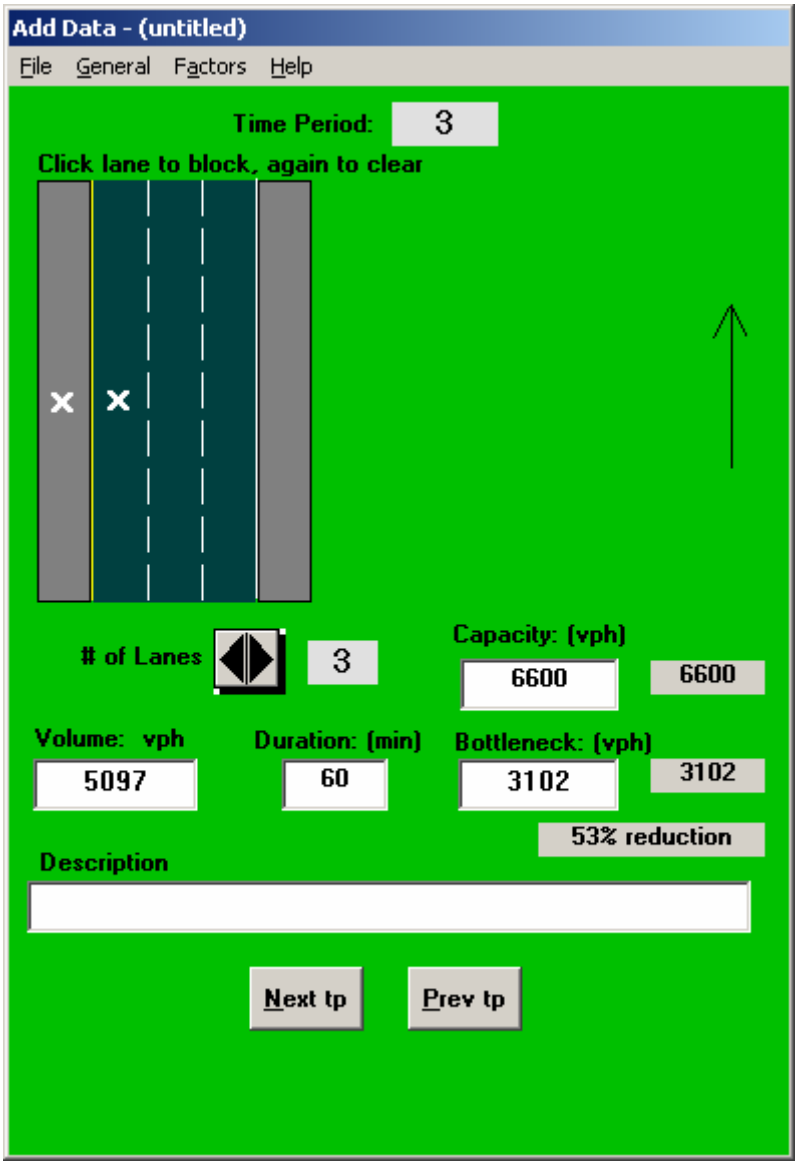


Figure 8-7: Third Hour Input for the Example Using DelayE.

By clicking on File on the main menu, Execute, and then the Results Summary button at top, the results will be shown as seen in Figure 8-8.

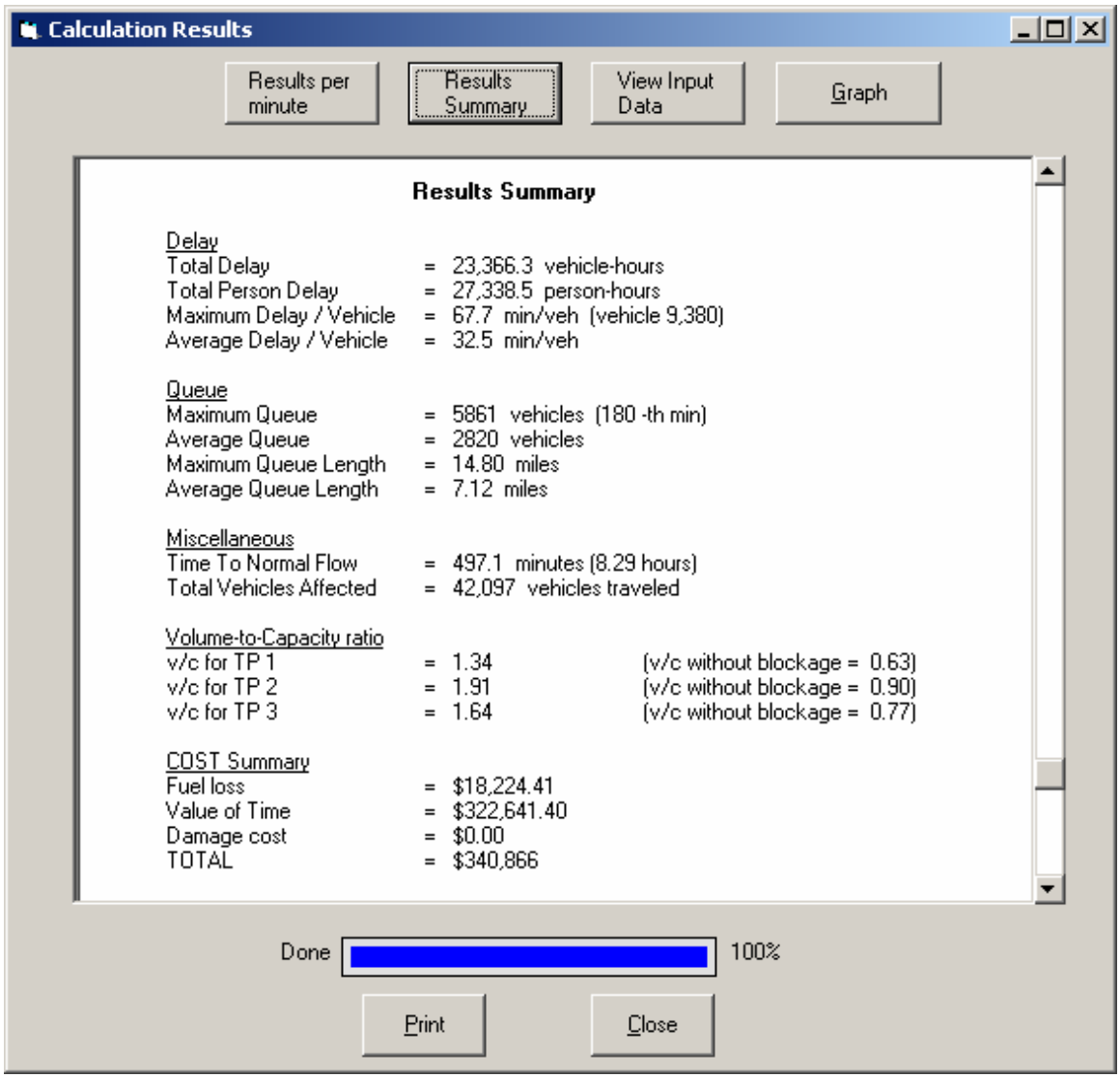


Figure 8-8: Results Summary for the Example Using DelayE.

As can be seen in this example, DUCK produces a result of $21,285 for the entire day's delay costs only. DelayE calculates $340,866 in total user costs due to queuing.

If DUCK's results are sufficient for use as an incentive on the project, then using DelayE may not be needed for the particular project. But DelayE's results are much larger, providing UDOT a larger, yet still justifiable, value to use.

Chapter 9. Conclusions and Recommendations

The objective of this thesis is to discuss work zone related user costs and how UDOT should estimate them for use in applying incentives in project management. This chapter summarizes the findings from the literature search, questionnaire, and interviews, and recommends a proceidure and computer programs. The chapter also addresses future research needs related to the topic of the study.

9.1 Results

A literature search was performed to discover how other states have employed user costs and how they calculated the values used. Proper planning and preparation should be used to ensure that the methods and values used are appropriate and justifiable. Adjustments to the calculated values of user costs should be made by the engineer.

The questionnaire survey of other SHAs indicates that the most popular methods for user cost estimation are simple and easy to use. The value of time should be estimated using the average wage of the state. Often, 50% of the average wage is used as a representative value of time in economic analyses; however, it depends on many factors. However, it is not a practice to use the full value (100%) of the average wage. A value between 50% and 75% appears to be reasonable.

Lost time or delay should be calculated using the extra time associated with reduced vehicle speeds through the work zone. Engineer's discretion should be allowed in adjusting determined user cost value.

Interviews involving UDOT employees were conducted to learn what they sought from a user cost plan and how they wanted the plan implemented. The results of the interviews indicate that the ease of use is a major quality desired by UDOT employees for a user cost plan. Similar to other state agencies, delay costs should be based on the speed reduction through the work zone. VOCs should be based on the cost of fuel. Other factors to use for calculations should include the AADT, length of the work zone, number of closed lanes, the day and time of the closure, the percentage of automobiles and trucks, and the functional class of the facility. Any computer programs should be intuitive and easy to use.

Four computer programs were presented, MicroBENCOST, QuickZone, DelayE, and DUCK. Each have strengths and weaknesses, but DelayE and DUCK encompass the ideals desired by UDOT employees for determining user costs.

9.2 Recommendations

DUCK and DelayE are recommended for use by UDOT because the combination of the two provides UDOT with the desired attributes mentioned previously. The DUCK program was created especially for UDOT using the objectives UDOT employees provided.

A plan is presented for UDOT to use by following the steps in the flow chart provided (see Figure 6-1). After DUCK is used for the speed reduction delay, DelayE

should be used to estimate the queue delay, if needed. These two programs can provide UDOT with a user cost value that is justifiable and reasonable.

This report should help UDOT make informed calculations for the values reflecting the user costs of those driving through work zones. Making reasonable estimations will assist UDOT in providing incentives to contractors to complete work sooner on Utah's highways.

9.3 Future Research

Further research in two areas is recommended to help UDOT enhance its capability to estimate work zone user costs for both access-controlled systems and surface-street networks. The first recommendation is to further study the benefits of QuickZone with regards to its ability to study the effects on detour routes. The second is to create a shell program to control both DUCK and DelayE to provide a smooth transition from DUCK to DelayE.

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Appendix A. Questionnaire Sent to State Highway Agencies

User Cost Questionnaire

The Utah Department of Transportation (UDOT) is in the process of developing a procedure to estimate user costs that can be charged to contractors and utility companies for the time work zones are set up and lanes or shoulders are closed to traffic. User costs can be used for assigning incentives and disincentives, cost/time bids, and for lane rental. In the course of this task, we are interested in knowing how your DOT is managing this issue.

Please take a few minutes to answer the following questions so that we may learn from your experiences. If you have any questions, please contact me by email or phone. Also, if your DOT has a manual or other material that is used for determining user costs, we request a copy of that as well. Please mail, fax or email the questionnaire and any other guidelines, reports, manuals, or other material, or a website address to find these materials online, to the following address:

Michael Adams, EIT
Research Assistant
Brigham Young University
Civil and Environmental Engineering Dept.
368 CB
Provo, UT 84602

Phone: 801-422-2685
Fax: 801-422-0159
Email: mra29@et.byu.edu

Thank you.

Note: This survey can be filled out on the computer in MS Word using pull-down lists and checkboxes, or you can print it and fill it out by hand. If completed on the computer, you can save the survey and send it as an attachment in email or print it out and mail it. In order for the checkboxes and formatting to work correctly to fill it out on the computer, the "Protect Form" button on the Forms toolbar must be active. Just click in the checkboxes to mark that answer, and click on the line for a pull-down list or to type in an answer.

1. Name: _____
   State: _____
   Address: _____
   Email: _____
   Phone: _____

2. Does your DOT use incentives* to encourage contractors and utility companies to minimize the amount of time lanes are closed in work zones?
   Answer: _____ (*click on the line - Yes, No, Not Sure*)
   If *No*, go to Question 19.

---

* *Although the term* incentive *may be considered a specific method to apply user costs to a project, for ease in writing these questions, it may be used generically to mean any application of a user cost, such as those in question 6, to encourage contractors, utility companies, and any others that create a work zone and especially those that close lanes to traffic.*

3. If a project has run longer than planned or lane rental charges have been applied to a project, has your DOT had problems with contractors or utility companies refusing to pay the charged costs for work zones and lane closures?

Answer: _____ (*click on the line - Yes, No, Not Sure*)

In how many projects have contractors or utilities refused to pay those charges since 1999?

Answer: _____ (*click on the line – Number of the projects*)

4. Is a project completed sooner than planned when using an incentive?

Answer: _____ (*click on the line - Yes, No, Not Sure*)

5. How has the quality of the work been affected when using an incentive?

Answer: _____ (*click on the line – Improved, Decreased, About the Same*)

6. Which method(s) does your DOT use for applying user costs to contractors and utility companies when closing shoulders and lanes of traffic and creating any work zones? Check all that apply.

☐ **INCENTIVE/DISINCENTIVE**
☐ **DISINCENTIVE ONLY**
☐ **COST/TIME**
☐ **COST/TIME WITH INCENTIVE/DISINCENTIVE**
☐ **LANE RENTAL**
☐ **NO METHOD**
☐ **OTHER** _____ (*click on the line to type an answer*)

If *No Method* is used, go to Question 19.

7. How does you DOT determine user costs? Check all that apply.

☐ **SIMPLE FORMULAS** – Basic algebraic equations
☐ **SPREADSHEETS** – Spreadsheets, such as MS Excel, or other tables created by your DOT or specially made for your DOT
☐ **HIGH LEVEL SOFTWARE** – Any software, especially those that are commercially available
☐ **AASHTO RED BOOK METHOD** – The actual method in the Red Book, or other spreadsheets based upon the Red Book method
☐ **FLAT RATES** – An amount set by legislation
☐ **NO FORMAL METHOD** – There is no formal method to determine user costs
☐ **OTHER** _____ (*click on the line to type an answer*)

8. What does your DOT use to determine the total user cost? Check all that apply.

☐ **DELAY COST**
☐ **VOC**
☐ **ACCIDENT COSTS**
☐ **ENVIRONMENTAL IMPACTS** (air pollution)
☐ **SOCIAL IMPACTS**
☐ **LEGISLATION OR POLICY**
☐ **NOT APPLICABLE –** total user cost not found
☐ **OTHER** _____ (*click on the line to type an answer*)

9. What information does your DOT use to determine the delay cost? Check all that apply.

☐ **NOT APPLICABLE –** Delay Costs not used. Go to Question 10.

Value of Time

☐ **AVERAGE WAGE** – of those in the city/region
☐ **REASON FOR TRAVEL** – work, commuting, errands, vacation, etc.
☐ **ABLE TO COMPLETE TASKS DURING THE COMMUTE** – cell phones, laptops, etc.
☐ **NUMBER OF PERSONS PER VEHICLE**
☐ **EXTRA TASKS THAT NEED TO BE COMPLETED** – daycare, bank, other non-work meetings, etc.
☐ **DAY OF WEEK**
☐ **TIME OF DAY**
☐ **OTHER** _____ (*click on the line to type an answer*)

Lost Time

☐ **DECELERATION** – normal flow to the reduced speed in the work zone
☐ **REDUCED SPEED** – normal flow compared to the speed in the work zone
☐ **ACCELERATION** – time spent accelerating from the reduced speed to the normal flow speed
☐ **BELOW CAPACITY QUEUE** – reduced speed approaching the work zone
☐ **ABOVE CAPACITY QUEUE** – time spent idling in the queue
☐ **DETOUR OR ALTERNATE ROUTE** – extra time spent traveling on a detour compared to the normal route.
☐ **OTHER** _____ (*click on the line to type an answer*)

How do you determine the lost time due to a detour?

☐ **BY HAND OR LOCAL KNOWLEDGE**
☐ **SOFTWARE**

Which software do you use? _____ (*click on the line to type an answer*)

10. What information does your DOT use to determine the VOC? Check all that apply.

☐ **NOT APPLICABLE –** VOCs not used. Go to Question 11.

☐ **FUEL**
☐ **OIL**
☐ **MAINTENANCE**
☐ **TIRE WEAR**
☐ **INSURANCE**
☐ **LICENSE**
☐ **DEPRECIATION**
☐ **INTEREST**
☐ **OTHER** _____ (*click on the line to type an answer*)

11. What information does your DOT use to determine the accident cost? Check all that apply.

☐ **NOT APPLICABLE –** Accident Costs not used. Go to Question 12.

☐ **TOTAL ACCIDENT RATE**
☐ **ACCIDENT RATE IN WORK ZONES**
☐ **COST OF DAMAGE**
☐ **COST OF INJURY**
☐ **COST OF DEATH**
☐ **OTHER** _____ (*click on the line to type an answer*)

12. What information does your DOT use to determine the cost of environmental impacts? Check all that apply.

☐ **NOT APPLICABLE –** Environmental Impact Costs not used. Go to Question 13.

☐ **EXTRA TIME IN THE WORK ZONE**
☐ **EXHAUST RATES IN THE WORK ZONE** compared to normal flow
☐ **WEIGHT OF POLLUTANTS PRODUCED**
☐ **OTHER** _____ (*click on the line to type an answer*)

13. What information do you use to determine the cost of social impacts? Check all that apply.
☐ **NOT APPLICABLE –** Social Impact Costs not used. Go to Question 14.

☐ **COST TO BUSINESSES DUE TO LOST REVENUE**
☐ **OTHER** _____ (*click on the line to type an answer*)

14. How do you adjust the determined user cost to apply it as an incentive for work zones and closing lanes of traffic? Check all that apply.
☐ **NO ADJUSTMENT IS MADE –** Go to Question 15.

☐ **USING PREDETERMINED MINIMUM AND MAXIMUM DOLLAR AMOUNTS SET BY THE DOT**
☐ **USING A PREDETERMINED PERCENTAGE OF THE DETERMINED USER COST**
☐ **ENGINEER'S DISCRETION**
Please describe how the engineer uses his discretion to adjust the charges for lane closures:
_____ (*click on the line to type an answer*)

15. What are the minimum and maximum incentives allowable by your DOT to pay contractors for completing a project early?
MINIMUM: $ _____ (*click on the line to type an answer*)
MAXIMUM: $ _____ (*click on the line to type an answer*)

16. What are the minimum and maximum disincentives allowable by your DOT to charge contractors for not completing a project on time?
MINIMUM: $ _____ (*click on the line to type an answer*)
MAXIMUM: $ _____ (*click on the line to type an answer*)

17. What are the minimum and maximum total dollar amounts for lane rental allowable by your DOT to charge contractors and utility companies?
MINIMUM: $ _____ (*click on the line to type an answer*)
MAXIMUM: $ _____ (*click on the line to type an answer*)

18. What percentage of the determined user cost does your DOT charge to contractors and utility companies?
Answer: _____

19. What are some recommendations to make a method for applying incentives to projects simple and easy to use?
Answer: _____ (*click on the line to type an answer*)

20. Please let us know of any other comments you have.
_____ (*click on the line to type an answer*)

Appendix B. Questionnaire for UDOT Personnel

User Cost Survey for UDOT

UDOT is in the process of producing a method based on user costs of the facility to charge contractors and utility companies for the time that they create work zones and close lanes to traffic. This charge should encourage contractors and utility companies to reduce the amount of time work zones are set up which will help to relieve congestion from work zones.

User costs can be used for incentives and disincentives, cost/time bidding practices, and for lane rental. Incentives and disincentives can be based upon the user cost of the facility where the work zone will be located. User costs are used with the cost/time bid by providing the contractors with a list of the cost of closing lanes and facilities at certain times of the day. This list allows them to create a timeline of the project and plan the best and least expensive times to complete then work. Lane rental can also use the list and will provide the cost to close lanes on facilities for a limited number of hours during the day. Hours of the day may vary in cost.

Thoughts on Charging User Costs

An established method throughout UDOT for charging user costs to contractors and utility companies will ensure that similar practices are held throughout the state, are based upon data, and will provide stability for both UDOT and other companies. Having a cost associated with closing lanes will encourage contractors and utility companies to complete the work more quickly and save time and money for the traveling public by reducing the time and distance spent in work zones.

Past and Current Practice

1. Do you charge any user costs now for projects, especially those that will involve closing the shoulder or lanes?

2. How do you decide what to charge?

3. Have contractors and utility companies contested the charged user costs?

4. Why did they feel they should not have to pay the extra charges?

Using a Method

UDOT would like to provide a simple method for those who use it.

5. Would you be willing to use a method to charge user costs if it were set throughout UDOT?

6. How should a method for charging user costs be arranged to make it easy to use and encourage you to use it?

7. Which method would you most likely use to determine the user cost for a project?
   - ☐ **By hand**
   - ☐ **Equations**
   - ☐ **Tables**
   - ☐ **Excel**
   - ☐ **Computer software such as:**
     - DelayE
     - Quickzone
     - MicroBENCOST
     - QUEWZ

8. Which costs should UDOT use to determine the total user cost?
   - ☐ **Delay**
   - ☐ **VOC (VOC)**
   - ☐ **Accident**
   - ☐ **Environmental Impacts**
   - ☐ **Social Impacts**
   - ☐ **Other**_____

9. How should the delay cost be determined?

   Lost Time due to
   - ☐ **Deceleration**
   - ☐ **Reduced speed through the work zone**
   - ☐ **Acceleration**
   - ☐ **Queue** (Demand > Capacity)
   - ☐ **Detour route**
   - ☐ **Other**_____

   Value of Time based upon
   - ☐ **Average wage**
   - ☐ **Average persons per vehicle**
   - ☐ **Ability to complete tasks in the vehicle** (cell phones, laptops, etc)
   - ☐ **Reason for travel** (commuting, work, errands, vacation, etc)
   - ☐ **Extra tasks that need to be done** (daycare, bank, other non-work meetings)
   - ☐ **Other**_____

10. How should VOCs be determined?
    - ☐ **Fuel**
    - ☐ **Tire**
    - ☐ **Oil**
    - ☐ **Maintenance**
    - ☐ **%Cars, %Trucks** (Utah does not have good truck data)
    - ☐ **License fee**
    - ☐ **Insurance**
    - ☐ **Depreciation**

- ☐ **Interest**
- ☐ **Accident costs**
- ☐ **Driver costs**
- ☐ **Management**
- ☐ **Overhead**
- ☐ **Other**_____

11. How should accident costs be determined? (Some DOTs do not have enough data to provide a good estimate for work zone accident rates.)
    - ☐ **Accident Rate Normally**
    - ☐ **Accident Rate in Work Zones**
    - ☐ **Cost of Vehicle Damage**
    - ☐ **Cost of Injury**
    - ☐ **Cost of Death**
    - ☐ **Other**_____

12. How should environmental impact costs be determined?
    - ☐ **Fuel**
    - ☐ **Carbon Monoxide**
    - ☐ **Hydrocarbons**
    - ☐ **Nitrous Oxides**
    - ☐ **Particulates**
    - ☐ **Other**_____

13. How should social impact costs be determined?
    - ☐ **Lost business**
    - ☐ **Other**_____

14. What information should tables be based on to determine the user costs?
    - ☐ **ADT**
    - ☐ **Length of the Work Zone**
    - ☐ **Number of Shoulders, Lanes Closed**
    - ☐ **Day of the Week**
    - ☐ **Time of Day**
    - ☐ **Delay Time**
    - ☐ **% Cars, % Trucks** (Utah does not have good truck data)
    - ☐ **Other**_____

Discretion

15. How should the determined user cost amount be adjusted?

16. Should the engineer provide an estimation of the time the project should take to complete to the contractor?

17. What should be a minimum and maximum payout for incentives?

18. What should be a minimum and maximum charge for disincentives?

19. What should be the minimum and maximum charge for lane rental?

20. Should the determined user cost automatically be adjusted using a certain percentage?