CONSTRUCTION CONGESTION COST

CO^3 USER MANUAL

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By Robert I. Carr

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CHAPTER 1

USING THE CO^3 SYSTEM

1.1 INTRODUCTION TO CO^3 USER MANUAL

The ***CO^3 User Manual*** consists of the following chapters:

Chapter 1 – Using the CO^3 System describes how to install the CO^3 system on a computer and provides basic directions for using the CO^3 system. The primary figures used are taken from Chapter 2, CO^3 Example Problem.

Chapter 2 – CO^3 Example Project provides a detailed example of using CO^3 on a project. For the example problem, it shows the use of CO^3 in making scope decisions and implementation decisions. By its examples, it explains the figures in Chapter 1.

Chapter 3 – Construction Travel Routes provides examples of using the Route Sheet for comparing alternative routes and for calculating equivalent values for routes made up multiple elements.

Chapter 4 – Using the CO^3 Flag System describes the application of CO^3 to congestion from two-way traffic that shares a single lane, in which traffic alternates in direction under the control of a flag person or other temporary signal system.

Chapter 5 – Traffic Demand and Delay Model describes the basic relationships, equations, and process by which CO^3 calculates traffic impacts, including actual demand, speed delay, and backup delay.

1.2 THE CO^3 SYSTEM

1.2.1 INTRODUCTION

1.2.1.1 General

The CO^3 System is a tool with which engineers can estimate the magnitude and impacts of traffic congestion, including its cost impact on road users, that can be expected during a construction project. Its name comes from the first two letters of COnstruction COngestion COst, on which the system focuses. From project conception through drafting provisions for maintaining traffic, CO^3 provides a useful way for engineers to include construction congestion and its costs to users as an important variable in all project decisions.

CO^3 measures the impact of congestion in two basic ways: (1) variables such as delay, diverted vehicles, and backup measure different characteristics of congestion and (2) user cost provides a common unit of measure with which to sum traffic impacts and compare them with construction cost. User costs consist of direct costs of increased travel distance due to traffic diversions and indirect costs that measure the impact of traffic delays and trip cancellations caused by congestion. CO^3 helps us select among alternative methods of maintaining traffic during construction, and it helps us select contract period costs for contract provisions that provide incentives for reducing congestion impacts during construction.

1.2.1.2 Acknowledgments

The CO^3 System was created by Robert I. Carr, with input from other members of the project team and financial support from the Michigan Department of Transportation. Kevin D. Matzke wrote early drafts of portions of Chapter 2, and he was an equal partner in developing the Traffic Sheet and Construction Cost Sheet and testing them on prototype projects. Robert Overby wrote early drafts of portions of Chapter 1.

1.2.2 BASIC STEPS OF CO^3

1.2.2.1 Introduction

The steps of CO^3 provide a reasonable match between the level of congestion impact that can be expected of a project and the level of attention given to congestion. We first want to determine if a project can be expected to have any significant congestion impact that warrants further study. If not, we can continue with project development without significant attention to congestion during construction. On the other hand, if it is evident that congestion during a project will seriously impact the traveling public, we need to apply CO^3 tools to estimate the impact and to compare alternative methods for maintaining traffic that reduce congestion.

1.2.2.2 Initial Investigation

We first perform an initial investigation to determine if congestion will have significant impact. If the initial investigation shows congestion will not have a significant impact during construction, we need not use CO^3 further. However, if the initial investigation shows congestion may well have significant impact, we must go further.

1.2.2.3 Estimating Impact of Preferred Method

We next apply CO3 software tools to the most preferred way of performing the work to get good estimates of congestion impacts. These include user cost = monetary value of extra travel time and distance that vehicles incur due to congestion. If congestion impact estimates indicate congestion will not be a significant problem during construction, we need not use CO^3 further. However, if congestion impacts are estimated to be significant, again we must go further.

1.2.2.4 Identifying and Comparing Alternatives

In the next step, we identify alternative methods of maintaining traffic during the project and determine their congestion impacts. We estimate the construction cost of any of the alternatives that have lower congestion impacts. We then compare the sum of user cost and construction cost for these alternatives. The comparison provides a measure of their overall practicality, to help select a practical method for maintaining traffic during the project. User costs calculated by CO^3 can be included with other project costs and benefits in project life cycle cost analyses.

1.2.2.5 Implementing the Selected Method

At this point, a method for maintaining traffic has been selected, and we have detailed estimates of its traffic and user cost impacts during construction. We also have an estimate of project cost attendant with using the selected method. The next step is to use CO^3 to help us select period costs and design contracting provisions which implement the selected method. As a final step, at project completion CO^3 calculates period cost resulting from actual lane closures, from which we determine actual contract costs and payment adjustments to contractors.

1.3 GETTING STARTED

1.3.1 INSTALLING CO^3

Use of CO^3 requires access to Microsoft Excel. Although not necessary, it is recommended that a computer with a Pentium CPU be used to minimize processing time.

Included with the *CO^3 User Manual* is a diskette that contains the file CO.xls (or C)95.xls for Excel 5.0/95). This is the master copy of the computer program. Our first step in using the program is to install it on the hard drive of the computer on which we will use it.

To install the model on our computer:

- turn on CPU
- access the hard drive (usually c:)
- at the c:, type: md CO
- insert the diskette containing CO into the "a" drive
- type: cd CO
- type: copy a:CO.xls (for Excel 97 or CO95.xls for Excel 5.0/95)

Following this procedure creates a sub-directory called CO that contains the program CO.xls.

To actually use CO.xls:

- access Microsoft Windows
- access Microsoft Excel
- open c:\CO\CO.xls (for Excel 97 or CO95.xls for Excel 5.0/95)

To save work for a project, we click on the "Save As" icon in the FILE menu. This prompts us to enter a file name under which the project will be saved. CO.xls is read-only protected, thus it can not be saved under its original name. Furthermore, each project must be saved under its own file name. Therefore, to create a new CO^3 file, we simply open CO.xls or another CO^3 workbook and save it under a new name.

As noted, the model is a Microsoft Excel based spreadsheet. It uses Visual Basic for much of its calculations, but operation of the model does not require an understanding of Visual Basic. The model does require the user to input data and work with a spreadsheet.

1.3.2 USING MICROSOFT EXCEL

1.3.2.1 Entering Data

The following description of Microsoft Excel assumes that the user is familiar with a keyboard and how it works.

A Microsoft Excel spreadsheet is configured in rows and columns. The intersection of a row and column is called a “cell”. We input data into some cells. Other cells contain equations or permanent numbers or text that we do not want to disturb. To input a value into a cell, we must first “select” the cell. We can select a cell using either the mouse or the keyboard arrow keys. To select a cell using the mouse, we (1) we move the cursor to the cell, and (2) we select the cell by pushing down with a finger on the left button of the mouse (for which we hereafter say “click”)[1]. To select a cell with keyboard arrow keys, we simply push the key that indicates the direction in which we want to move, and the cursor selects the next cell(s) in that direction. We know a particular cell is selected when it is outlined by a border that is thicker than borders around cells that are not selected. Once we have selected the appropriate cell, we type on the keyboard the letters or numbers we want to input. When we have typed all the letters or numbers, we then push the “Enter” key. This enters the data into the cell.

To leave the cell contents unchanged, even if we have started typing in the cell, push the “Escape” key, which is often marked “Esc.” If we wish to reverse an entry into the cell into which we have just input data, we can push the “undo” icon . Another way to “undo” is to push the “Control” key, often marked “Ctrl”, then the letter “z” without releasing “Control”. We call this simultaneous pushing of “Ctrl” and “z” keys “Ctrl-z”.

We enter and edit data by selecting the desired cell and typing on the keyboard as described above. To erase the value in a cell, we select the cell, then we push the “Delete” key on the keyboard. The cell will become blank. To change the value in a cell, we select the cell and edit the old value or enter a new value, without first having to delete the old value. For example, if a cell contains the value “4.37” and we want it to contain the value “4.8”, we select the cell, then either (1) we change the “37” to “8”, or (2) we input “4.8”.

Additional information pertaining to the use of Microsoft Excel can be found in the Microsoft Excel help menu or users guide.

1.3.2.2 Workbooks and Worksheets

The basic Excel file is called a “workbook.” A workbook contains “worksheets,” also called “sheets,” each of which is an individual spreadsheet. Some CO^3 sheets contain several “views,” each of which is a different part of the sheet. Therefore, a user can go to an individual view within a sheet in a workbook. Generally, we will use one workbook for each project, and a project workbook will contain several sheets, each of which represents an CO^3 module. To make a new CO^3 workbook, open any CO^3 workbook, then save it under a new name.

Sheet tabs located near the bottom of a window show the names of the various sheets a workbook contains. We activate one sheet at a time, to see it and work in it. To access any sheet, we move the cursor to the desired sheet tab and click. The figure below shows pointers to the

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1 Most commonly we click the left side of the mouse, called “click” the mouse or “L-click.” We can also click the right side of the mouse, called “R-click.”

“traffic” tab (the active sheet) and the “input” tab. To make an additional sheet of a particular type, we R-click (push the button on the right side of the mouse) the cursor on the sheet’s tab to get a menu, select “Move or Copy” from the menu to get the “Move or Copy” window, check “Create a copy” and click OK, which creates a copy of the original sheet. We can change the name of a sheet on its tab in either of two ways: (1) double click on the tab to highlight the name, then edit the name, or (2) R-click on the tab to get a menu, select “Rename” on the menu to highlight the name, then edit the name.

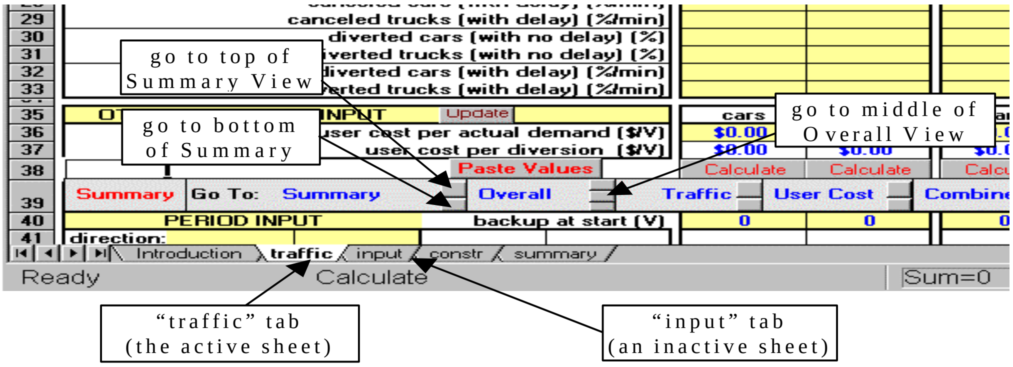


Fig. 1-1 Workbook Tabs and Summary Sheet Navigation Buttons

1.3.2.3 CO^3 Navigation Buttons

The CO^3 Traffic Sheet and Daily Sheet have buttons that enable us to access any view by clicking on the desired button. We just move the cursor to the buttons located anywhere on the sheet, position the cursor on the desired button and click. The figure below has pointers to buttons to go to the top of the Summary View, go to the bottom of Summary View, and go to middle of the Overall View.

1.3.2.4 Copy and Paste Values

Copying data from cell(s) to cell(s) is useful, especially for traffic demand or capacity. To do this, we “Copy” the data in the origin cell(s) and “Paste Value” it into the destination cell(s). To Copy: we (1) select the cell(s) containing the desired data by clicking on the upper left portion of the data and drag the cursor to the lower left portion of the data while holding the left button of the mouse, and (2) either (a) click on the Copy icon on the toolbar or (b) type Ctrl-C on the keyboard or (c) click on Edit on the toolbar and Copy on its foldout menu. To Paste Value: we (1) select the cell(s) in which to Paste Value the desired data by clicking on the upper left cell, and (2) either (a) click the Paste Value icon on the toolbar or (b) click the Paste Values icon Paste Values on the worksheet (where available) or (c) click on Edit on the toolbar, click Paste Special on its foldout menu, click Values and then OK on the Paste Special window.

1.3.2.5 Copy and Paste Worksheet Sections to Documents

The preferred way to copy a portion of a worksheet into a word processing program is to highlight it, Copy it, and Paste it into the word processing document. When using Excel 97, copying is best done by holding down the Shift key with L-click on Edit, then L-click on Copy Picture on the Edit menu. To copy into Word 97, L-click on Edit, L-click on Paste Special to get

Paste Special window. In Paste Special window, L-click on Picture, then L-click on "Float over text" to remove its ✓.

To change the format of the picture in Word 97, we can R-click on the picture to get a menu, then click Format Picture to get Format Picture window. For example, to change the size of the picture, in Format Picture window, click Size tab to get the Size window. In Size window, click "Relative to original picture size" to remove its ✓, click in either Height or Width in the Size and Rotate section and enter the height or width desired, then click OK.

We can also Copy and Paste portions of worksheets into word processing documents in "Landscape" page orientation. An example of this is the Daily Cost View in this document. The method is explained in Sec. 1.7.2.6, pg. 1-73.

1.4 OVERVIEW OF CO^3

1.4.1 INTRODUCTION

The CO^3 computer program consists of the CO.xls file, which in Excel is called a "work-book". The workbook contains "worksheets", which we also call "sheets". These sheets can have more than one module, which we often call a "view" when it is a separate item which can be printed separately as a report. Below is a list of the sheets and modules that make up the CO^3 computer program, with a short description of the purpose of each.

1.4.2 LIST OF CO^3 COMPUTER PROGRAM ELEMENTS

- **A. Input Sheet (input tab) –** Field input and documentation of project data and calculation of travel data to assist Traffic Sheet input and documentation of decreases to demand (see Fig. 1-2, pg. 1-9).
- **B. Routes Sheet (routes tab) –** Project input and calculation of travel data (1) for multiple alternative routes and (2) for complex routes (see Fig. 1-5, pg. 1-20).
  - **B.1. Route Distance, Speed, and Time –** Equivalent project input for routes made up of different road segments or a group of alternative routes.
  - **B.2. Route User Costs –** For several alternative routes.
- **C. Traffic Sheet (traffic tab) –** Input of project data and calculation of traffic impact and user cost.
  - **C.1. Summary View –** Input and calculation and summarization of traffic impact and user cost for up to four traffic maintenance methods (see Fig. 1-6, pg. 1-27).
  - **C.2. Overall View –** Report of input and hourly traffic and user cost impact for the most recently calculated traffic maintenance method and direction (see Fig. 1-10, pg. 1-37).
  - **C.3. Traffic View –** Report of input and hourly traffic impact for the most recently calculated traffic maintenance method and direction (see Fig. 1-11, pg. 1-39).
  - **C.4. User Cost View –** Report of input and hourly user cost impact for the most recently calculated traffic maintenance method and direction (see Fig. 1-12, pg. 1-40).
  - **C.5. Combined View –** Report of input and a selected set of hourly traffic and user cost impact for the most recently calculated traffic maintenance method and direction (see Fig. 1-13, pg. 1-41).

D. **Construction Cost Sheet (construction tab) –** Input of construction cost estimates and calculation of estimated project cost for alternative traffic maintenance methods (see Fig. 1-14, pg. 1-44).

E. **Impact Sheet (impact tab) –** Summarization of impacts of alternative traffic maintenance methods (see Fig. 1-15, pg. 1-56).

   E.1. Summary Input – Input of project traffic, user cost, and construction cost impacts from Summary View and Construction Sheet.

   E.2. Summary of Impacts – Report of daily user cost, total user cost, construction cost, and project cost for alternative traffic maintenance methods.

F. **Daily Cost Sheet (daily tab) –** Calculate daily traffic impact cost for any set of traffic maintenance hours, for any round-off or fraction of user cost.

   F.1. User Cost View – Input of hourly user cost (see Fig. 1-16, pg. 1-68).

   F.2. Period Cost View – Period cost calculated as rounded-off fraction of user cost (see Fig. 1-19, pg. 1-74).

   F.3. Detailed Cost View –A more detailed view of period costs for manual calculation of traffic impact cost (see Fig. 1-21, pg. 1-76).

   F.4. Daily Cost View – The most detailed view of period costs, which includes table of all possible traffic maintenance hours (see Fig. 1-22, pg. 1-77).

   F.5. Project Cost View – Calculates cost for each day, for any arrangement of lane-closed hours, including actual lane-closed hours for the duration of the project (see Fig. 1-24, pg. 1-80).

1.5 USING CO^3 TO CALCULATE CONGESTION IMPACT

1.5.1 INPUT SHEET

1.5.1.1 General

The Input Sheet provides a form that helps us identify and estimate values of variables that are important for input to the Traffic Sheet. The Input Sheet is not particularly important in itself, because most of its values will be repeated in the Traffic Sheet. It has two basic uses: (1) It provides an easy format for handwritten specification and documentation of input values, which can be done separate from a computer. (2) It provides for computer input, calculation, and documentation of project travel data for entry into the Traffic Sheet. The first of these, which we call "Field Input," is shown in 0. The second is shown in Fig. 1-2. Inputs are generally for both directions of travel.

Inputs to the Input Sheet are shown in color on the monitor and in light gray here. On the left end of each input row is a circled number, such as ①, which indicates the sequence in which data is normally input. Default values are indicated by ⓪. The general steps are the following:

1. Input general inputs related to project.
2. Input variables with values up to ③.
3. Calculate travel and user cost values.
4. Estimate remaining input values, based on calculations, for use in Traffic Sheet.

Use of each section of the Input Sheet is described below, accompanied by an unnumbered figure representing the section.

1.5.1.2 General Input

PROJECT INPUT AND DOCUMENTATION		Project:	US 00 Overlay (Example Problem)
WITH PUBLICITY		By:	R. I. Carr, 10/18/96
Copy This Sheet		Other:	
METHOD INPUT	METHOD 2		6 mi of overlay, West from Maple. Do 3 x 4 lanes x 2 mi segments x 1 day each. US 00 is 2 lanes each way.
method title	WITH PUBLICITY		Traffic count: Jun13-14, 96. Fast growing area: est traffic growth=5%. Growth = 2 yr for 1998 project.

Input **Project** and **By** to identify the project and person who is analyzing the project. Input of **method number** and **method title** is useful to identify the particular traffic maintenance method for which input values are selected. Other notes should be added as useful to document estimates, measurements, and decisions. A copy of the Impact Sheet, in the form of another "impact" tab, can be created by clicking the **Copy This Sheet** button.

1.5.1.3 Vehicle Input

VEHICLE INPUT		cars	trucks	
1	design demand (%)	90.0%	10.0%	Est
0	user cost per hour ($/V hr)	$10.79	$10.79	default
0	user cost per mile, ($/V mi)	$0.30	$1.00	default
4	user cost per cancellation, ($/V)	$1.00	$2.00	About 2/3 diversion cost.

Design demand, trucks is the fraction of design demand that we estimate is trucks (versus cars), which we determine from a traffic count or we estimate it from experience. Default values are input for **user cost per hour** and **user cost per mile**. Current default values are shown above. **User cost per cancellation** is estimated based on calculated **travel** and **user cost** values that are described below.

1.5.1.4 Capacity Input

CAPACITY INPUT		normal	method	
1	total capacity each way (V/hr)	3400	1400	Est. Normal = typical 2 lane in one direction.Method = 1 lane, close to work, w/ large asphalt trucks: C=90%(1550)

Method travel is travel under traffic maintenance, during construction, and **normal** travel is travel without construction. The **capacity** of the roadway is the number of vehicles per hour it can carry. We must estimate the capacity of the roadway under normal and method conditions before we estimate values of other variables. We input capacity here, to document its estimation.

	PROJECT INPUT AND DOCUMENTATION		Project:	**US 00 Overlay (Example Problem)**
	WITH PUBLICITY		By:	R. I. Carr, 10/18/96
	Copy This Sheet		Other:	
	METHOD INPUT	METHOD 2		6 mi of overlay, West from Maple. Do 3 x 4 lanes x 2 mi segments x 1 day each. US 00 is 2 lanes each way.
	method title	WITH PUBLICITY		Traffic count: Jun13-14, 96. Fast growing area: est traffic growth=5%. Growth = 2 yr for 1998 project.
	VEHICLE INPUT	cars	trucks	
1	design demand (%)	90.0%	10.0%	Est
0	user cost per hour ($/V hr)	$10.79	$10.79	default
0	user cost per mile, ($/V mi)	$0.30	$1.00	default
4	user cost per cancellation, ($/V)	$1.00	$2.00	About 2/3 diversion cost.
	ROUTE TITLES	Standard		
	DISTANCE AND SPEED INPUT	distance	speed	
1	work zone method travel	2.0	see delay	Close 1 lane, 2 mi at a time.
1	work zone normal travel	2.0	65	Est, from driving it.
1	diversion method travel	12.0	50	Maple - Old 00 - Spruce = 12 mi @ 50 MPH, Est from driving.
1	diversion normal travel	10.0	65	Maple to Spruce on US 00 = 10 mi @ 65 MPH. Est from driving.
	SPEED DELAY INPUT	threshold	range	
2	capacity for speed delay (V/hr)	1400		Est 1 lane capacity = 1400 VPH
3	speed (when D~0) (mph)	45		Est, for low traffic
3	speed (when D=C) (mph)	10		Est, for demand => capacity
	WORK ZONE TRAVEL	threshold	range	General Comments:
	normal travel time (min)	1.85		
	method travel time (when D~0) (min)	2.67		Demand is W of Maple, West of Maple, NW = Tu, 29 Aug 95, SE = Wed, 30 Aug 95.
	speed delay (when D~0) (min)	0.82		
	method travel time (when D=C) (min)	12.00		Info based on personal drive, Tu, 5 Dec 95, about 3 PM.
	speed delay (when D=C) (min)	10.15		
	ZONE SPEED DELAY USER COST	threshold	range	Alternate route can handle trucks, but it is a little tight. Old 00 is posted at 55 MPH. Spruce and Maple posted at 45 MPH, w/ 2-way stop signs at Old 00. Most of demand is not familiar with alternate route.
	car speed delay user cost (when D~0)	$0.15		
	truck speed delay user cost (when D~0)	$0.15		
	car speed delay user cost (when D=C)	$1.83		
	truck speed delay user cost (when D=C)	$1.83		
	DIVERSION TRAVEL			
	method travel time (min)	14.40		
	normal travel time (min)	9.23		
	diversion delay (min)	5.17		
	extra diversion travel distance (mi)	2.0		
	DIVERSION USER COST	cars	trucks	
	diversion delay user cost	$0.93	$0.93	
	diversion distance user cost	$0.60	$2.00	
	diversion user cost	$1.53	$2.93	
	backup delay balance (min)	-1.65	6.14	
	DECREASE TO DEMAND	threshold	range	
2	capacity for decreases to design demand (V/hr)	1400		Assume no decreases except when a lane is closed, when C=1400 VPH. Therefore, no range input.
6	canceled cars (with no delay) (%)			Blank, because of good publicity
6	canceled trucks (with no delay) (%)			Blank, because of good publicity
6	canceled cars (with delay) (%/min)	3.0%		Est 25% @ (10.15 - 1.65 min) ~ 3%/min
6	canceled trucks (with delay) (%/min)	1.0%		Est 20% @ (10.15 + 6.14) ~ 1%/min
5	diverted cars (with no delay) (%)			Blank, because of good publicity
5	diverted trucks (with no delay) (%)			Blank, because of good publicity
5	diverted cars (with delay) (%/min)	3.0%		Est [40% * (1 - 25%) = 30%] @ (10.15 - 1.65 = 8.5 min) ~ 3%/min
5	diverted trucks (with delay) (%/min)	1.0%		Diversion is tight for trucks. Est 20% @ (10.15 + 6.14) ~ 1%/min
	OTHER USER COST INPUT	cars	trucks	
	other user cost per vehicle ($/V)	$0.00	$0.00	default
	user cost per diversion ($/V)	$1.53	$2.93	
	CAPACITY INPUT	normal	method	
1	total capacity each way (V/hr)	3400	1400	Est. Normal = typical 2 lane in one direction.Method = 1 lane, close to work, w/ large asphalt trucks: C=90%(1550)

Fig. 1-2 Input Sheet

1.5.1.5 Distance and Speed Input

ROUTE TITLES	Standard		
DISTANCE AND SPEED INPUT	distance	speed	
(1) work zone method travel	2.0	see delay	Close 1 lane, 2 mi at a time.
(1) work zone normal travel	2.0	65	Est, from driving it.
(1) diversion method travel	12.0	50	Maple - Old 00 - Spruce = 12 mi @ 50 MPH, Est from driving.
(1) diversion normal travel	10.0	65	Maple to Spruce on US 00 = 10 mi @ 65 MPH. Est from driving.

Distance and speed have two categories of input: work zone and diversion. Each of these is further divided into method travel and normal travel. Method travel refers to the travel route and its conditions during construction, and normal travel refers to the travel route and its conditions without construction. The distance and speed traveled are required inputs for these categories.

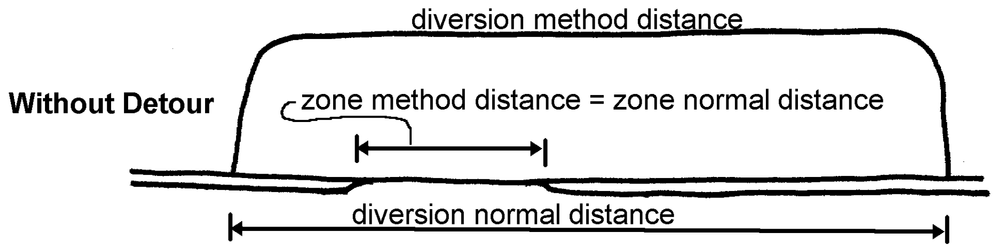
The model requires the following four distances to be input:

- **work zone method travel distance** = distance each vehicle will travel through the work zone during construction, or a required detour around the work zone, if present.
- **work zone normal travel distance** = distance each vehicle will travel if there is no construction, no work zone.
- **diversion method travel distance** = length of the most common alternate route vehicles will select to avoid going through the work zone or a required detour around the work zone. If there are several alternate routes, it is the average of the comparable lengths, weighted by the number of vehicles expected to take each of them.
- **diversion method normal distance** = distance each vehicle would travel if there were no work zone and the vehicle did not divert to an alternate route.

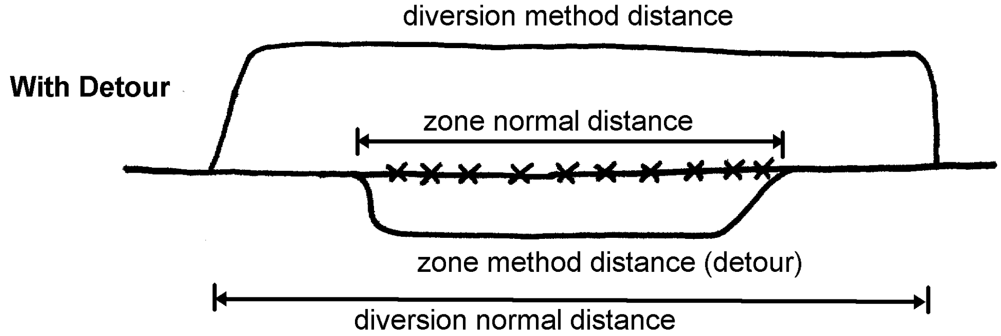
Work zone method travel distance = work zone normal travel distance, except when there is a detour, in which case work zone method travel distance is the length of the detour. We input estimates for speed here, except for work zone method travel speed, which is separately calculated from Speed Delay Input. Fig. 1-3 illustrates the travel distances defined above.

Speeds within work zones are also classified by normal travel speed and method travel speed:

- **work zone normal travel speed** = average speed vehicles will travel if there is no work zone.
- **diversion method travel speed** = average speed vehicles that divert will travel on the diversion route.
- **diversion normal travel speed** = average speed vehicles travel over the diversion normal travel distance, when there is no work zone.
- **work zone method travel speed** = speed vehicles travel through the work zone during construction, based on conditions that vary with demand and capacity in the work zone. This is calculated by CO^3 based on input described below.



a. Without Detour



b. With Detour

Fig. 1-3 Work Zone and Diversion Distances

1.5.1.6 Speed Delay Input

SPEED DELAY INPUT		threshold	range	
2	capacity for speed delay (V/hr)	1400		Est 1 lane capacity = 1400 VPH
3	speed (when D~0) (mph)	45		Est, for low traffic
3	speed (when D=C) (mph)	10		Est, for demand => capacity

Vehicle speed through a construction zone may be lower than speeds outside the zone, due to pavement conditions, traffic conditions, routing through a detour, or other work zone conditions. If a detour is used, it may also add distance to a trip, thus increasing travel time. Traffic control, such as one-way travel through the zone or other use of flaggers or signals that produce stop-and-go traffic, can also increase travel time.

Speed delay is the difference in time to travel the method travel distance through the work zone (or around it if a detour is required) during construction and the time it would take if there were no construction. **Threshold capacity for speed delay** is the capacity at and below which speed delay occurs. Speed delay is calculated for all periods with capacity ≤ (threshold capacity for speed delay), which allows speed delay of a vehicle to vary as work zone conditions and traffic conditions change. Work zone conditions change from time to time as lanes or ramps are closed and opened or as traffic is routed over temporary paving or detours. Therefore, work zone conditions change when capacity changes. Traffic conditions change as work zone conditions change and as demand changes. Speed delay is modeled as a function of capacity and demand.

That is, each period with capacity ≤ (threshold capacity for speed delay) has a speed delay function, and for each period the value of its speed delay is a function of the ratio D/C = (demand that enters the zone during the period) / (period capacity), and D/C can have any value between 0 and 1.

The speed delay function for each period with capacity ≤ (threshold capacity for speed delay) is therefore defined by three variables:

- **capacity for speed delay** = capacity for the period.
- **speed (when D~0)** = speed when demand is very low.
- **speed (when D=C)** is the speed when the number of vehicles that enter the zone during the period is limited by its capacity.

For cases where different periods have different capacities and the different capacities have speeds that differ from normal travel speed, another set of values, called **range inputs**, is needed in addition to threshold inputs. When there are range inputs, the computer calculates speed delay by interpolating between the threshold inputs for the threshold capacity and the range inputs for the range capacity.

Therefore, the model allows two possible sets of input for speed delay estimates: **threshold input** and **range input**. Modeling of threshold and range inputs and calculation of speed delay are described in detail in Sec. 5.3, pg. 5-2. For each traffic maintenance alternative, we choose one of the following three cases:

Case 1: Input no values: Leave threshold and range cells empty:

SPEED DELAY INPUT		threshold	range
2	capacity for speed delay (V/hr)		
3	speed (when D~0) (mph)		
3	speed (when D=C) (mph)		

- For all periods (work zone method travel speed) = (work zone normal travel speed), (speed delay) = 0, and (speed delay user costs) = 0.

- In this example, (work zone method travel speed) = (work zone normal travel speed) = 65 mph (from input in Sec. 1.5.1.5) for all periods.

Case 2: Input values for threshold only, leave range cells empty:

SPEED DELAY INPUT		threshold	range
2	capacity for speed delay (V/hr)	1400	
3	speed (when D~0) (mph)	45	
3	speed (when D=C) (mph)	10	

- For periods with capacity > (threshold capacity for speed delay), then (work zone method travel speed) = (work zone normal travel speed), (speed delay) = 0, and (speed delay user costs) = 0 for all demands.

- For periods with capacity ≤ (threshold capacity for speed delay), then (work zone method travel speed) varies from [threshold speed (when D≈0)] to [threshold speed (when D=C)], depending on actual demand.

- In this example, (work zone method travel speed) = 65 mph for periods that have capacity > 1400 V/hr, and (work zone method travel speed) varies from 45 mph to 10 mph, depending on actual demand, for periods that have capacity ≤ 1400 V/hr.

Case 3: Input values for both threshold and range cells:

SPEED DELAY INPUT		threshold	range
2	capacity for speed delay (V/hr)	1400	1,000
3	speed (when D~0) (mph)	45	30
3	speed (when D=C) (mph)	10	10

- For periods with capacity > (threshold capacity for speed delay), then (work zone method travel speed) = (work zone normal travel speed), (speed delay) = 0, and (speed delay user costs) = 0 for all demands.
- For periods with capacity = (threshold capacity for speed delay), then (work zone method travel speed) varies from [threshold speed (when D≈0)] to [threshold speed (when D=C)], depending on actual demand.
- For periods with capacity = (range capacity for speed delay), then (work zone method travel speed) varies from [range speed (when D≈0)] to [range speed (when D=C)], depending on actual demand. For all other periods with capacity ≤ (threshold capacity for speed delay), then (work zone method travel speed) is interpolated based on threshold and range capacities.
- In this example, (work zone method travel speed) = 65 mph for periods that have capacity > 1400 V/hr. (work zone method travel speed) varies from 45 mph to 10 mph, depending on actual demand, for periods that have capacity = 1400 V/hr. (work zone method travel speed) varies from 30 mph to 10 mph, depending on actual demand, for periods that have capacity = 1000 V/hr. For periods with capacity = 1300 V/hr interpolation produces [speed (when D≈0)] = 30 + (45 – 30) * [(1300 – 1000) / (1400 – 1000)] = 30 + (15) * [300 / 400] = 33.75 mph.

An example using range variables is a case in which travel speed through the work zone when no lanes are closed is expected to be less than normal travel speed, due to work zone signing and consetruction conditions. There would be speed delay for all periods, and the speed delay variable values would differ. Therefore, we input threshold values to describe conditions when no lanes are closed, and we input range values to describe conditions when a lane is closed.

We require [normal speed] ≥ [speed at threshold capacity (when D~0)] ≥ [speed at threshold capacity (when D=C)], otherwise CO^3 calculations stop and show a fatal error message. Similarly, we require [range capacity for speed delay] < [threshold capacity for speed delay], [speed at threshold capacity (when D~0)] ≥ [speed at range capacity (when D~0)], and [speed at threshold capacity (when D=C)] ≥ [speed at range capacity (when D=C)].

1.5.1.7 Calculation of Vehicle Travel and User Cost

WORK ZONE TRAVEL	threshold	range	General Comments:
normal travel time (min)	1.85		
method travel time (when D~0) (min)	2.67		Demand is W of Maple, West of Maple, NW = Tu, 29 Aug 95, SE = Wed, 30 Aug 95.
speed delay (when D~0) (min)	0.82		
method travel time (when D=C) (min)	12.00		Info based on personal drive, Tu, 5 Dec 95, about 3 PM.
speed delay (when D=C) (min)	10.15		
ZONE SPEED DELAY USER COST	threshold	range	Alternate route can handle trucks, but it is a little tight. Old 00 is posted at 55 MPH.
car speed delay user cost (when D~0)	$0.15		Spruce and Maple posted at 45 MPH, w/ 2-way stop signs at Old 00. Most of
truck speed delay user cost (when D~0)	$0.15		demand is not familiar with alternate route.
car speed delay user cost (when D=C)	$1.83		
truck speed delay user cost (when D=C)	$1.83		
DIVERSION TRAVEL			
method travel time (min)	14.40		
normal travel time (min)	9.23		
diversion delay (min)	5.17		
extra diversion travel distance (mi)	2.0		
DIVERSION USER COST	cars	trucks	
diversion delay user cost	$0.93	$0.93	
diversion distance user cost	$0.60	$2.00	
diversion user cost	$1.53	$2.93	
backup delay balance (min)	-1.65	6.14	

Zone speed delay user cost is the user cost per vehicle that travel through the work zone (or detour). It is due to speed delay in the work zone, and it is calculated by applying user cost per hour, and user cost per mile to speed delay. **Diversion user cost** is the user cost per vehicle that diverts. It is calculated by applying user cost per hour, and user cost per mile to extra method travel distance (which is not shown in Input Sheet), diversion delay, and extra diversion travel distance. **Backup** occurs when actual demand exceeds capacity, and vehicles must wait to enter the work zone. **Backup delay** (min) is the length of time between a vehicle's arrival at the backed-up queue and its reacing the front of the queue and entering the work zone. **Backup delay balance** is the amount of backup delay at which (backup user cost) = (diversion user cost). Backup delay balance is negative, if (diversion user cost) < [speed delay user cost (when D=C)].

CO^3 calculates extra travel distance and user cost based on:

extra travel distance (mi) = (method travel distance) – (normal travel distance) (1)

from which we calculate extra travel distance and distance user cost through the work zone (or detour) and around it:[2]

extra work zone travel distance (mi) = (work zone method travel distance) – (work zone normal travel distance) (2)

extra diversion travel distance (mi) = (diversion method travel distance) – (diversion normal travel distance) (3)

CO^3 calculates travel time and related delay and delay user cost based on

$$\text{travel time (min)} = \frac{[\text{travel distance (mi)}](60\ \text{min/hr})}{[\text{travel speed (mph)}]} \quad (4)$$

delay (min) = (method travel time) – (normal travel time) (5)

from which CO^3 calculates delay through the work zone (or detour) and around it:

speed delay (min) = (work zone method travel time) – (work zone normal travel time) (6)

---

[2] Extra work zone travel distance is not shown in CO^3, because extra work zone travel distance = 0 unless there is a detour. However, its user cost is included in speed delay user cost.

diversion delay (min) = (diversion method travel time) – (diversion normal travel time) (7)

The CO^3 speed delay model and calculations are described in more detail in Sec. 5.3, pg. 5-2.

CO^3 calculates delay user cost and total user cost based on

distance user cost ($/V) = [extra travel distance (mi)] * [user cost per mile ($/mi)] (8)

delay user cost ($/V) = [delay (hr)] * [user cost per hour ($/V-hr)] (9)

user cost ($/V) = delay user cost + distance user cost (10)

from which we calculate user cost of travel through the work zone (or detour) and around it:

speed delay user cost ($/V) = [speed delay (hr)] * [user cost per hour ($/V-hr)] + [extra work zone travel distance (mi)] * [user cost per mile ($/mi)] (11)

diversion distance user cost ($/V) = [extra diversion travel distance (mi)] * [user cost per mile ($/mi)] (12)

diversion delay user cost ($/V) = [diversion delay (hr)] * [user cost per hour ($/V-hr)] (13)

diversion user cost ($/V) = (diversion delay user cost) + (diversion distance user cost) (14)

CO^3 calculates backup delay balance from:

$$\text{backup delay balance (min)} = \frac{[\text{diversion user cost (\$)}] - [\text{speed delay user cost (\$)}]}{[\text{user cost per hour (\$ / hr)}] * [60 \text{ (min / hr)}]} \quad (15)$$

1.5.1.8 Decrease to Demand

DECREASE TO DEMAND		threshold	range	
2	capacity for decreases to design demand (V/hr)	1400		Assume no decreases except when a lane is closed, when C=1400 VPH. Therefore, no range input.
6	canceled cars (with no delay) (%)			Blank, because of good publicity
6	canceled trucks (with no delay) (%)			Blank, because of good publicity
6	canceled cars (with delay) (%/min)	3.0%		Est 25% @ (10.15 - 1.65 min) ~ 3%/min
6	canceled trucks (with delay) (%/min)	1.0%		Est 20% @ (10.15 + 6.14) ~ 1%/min
5	diverted cars (with no delay) (%)			Blank, because of good publicity
5	diverted trucks (with no delay) (%)			Blank, because of good publicity
5	diverted cars (with delay) (%/min)	3.0%		Est [40% * (1 - 25%) = 30%] @ (10.15 - 1.65 = 8.5 min) ~ 3%/min
5	diverted trucks (with delay) (%/min)	1.0%		Diversion is tight for trucks. Est 20% @ (10.15 + 6.14) ~ 1%/min

Some drivers may divert to other routes or cancel trips to avoid the work zone and the delay associated with it. These actions decrease demand through the work zone (or detour). Thus, actual demand will be less than design demand due to diverted and canceled vehicles. At any capacity, the decrease in traffic due to diverted and canceled vehicles is modeled in four components for both cars and trucks:

- **decrease (with no delay)** = **diverted (with no delay)** + **canceled (with no delay)** traffic that occurs even in periods in which there is no significant delay at the work zone. This is expressed in percent.
- **decreases (with delay)** = **diverted (with delay)** + **canceled (with delay)** traffic that occurs due to delay at the work zone. This is expressed in percent decrease per minute of delay.

Threshold capacity for decreases to design demand is the capacity at and below which diversions and cancellations occur. Decreases to design demand are calculated for each period that has capacity ≤ (threshold capacity for decreases to design demand), based on **threshold inputs**. For cases where different periods have different capacities and different decrease functions, another set of values, called **range inputs**, is needed in addition to threshold inputs. When there are range inputs, the computer calculates demand decreases by interpolating between the threshold inputs for the threshold capacity and the range inputs for the range capacity. Modeling of threshold and range inputs and calculation of demand decreases are described in Sec. 5.4, pg. 5-7

Therefore, in parallel with speed delay, the model allows two possible sets of input variables for input of percent decrease in demand estimates: threshold input and range input. For each traffic maintenance alternative, we choose one of the following three cases:

Case 1: Input no values: Leave threshold and range cells empty:

DECREASE TO DEMAND		threshold	range
2	capacity for decreases to design demand (V/hr)		

- For all capacities, (decreases in demand) = 0, and (actual demand) = (design demand).

Case 2: Input values for threshold only, leave range cells empty:

DECREASE TO DEMAND		threshold	range
2	capacity for decreases to design demand (V/hr)	1400	
6	canceled cars (with no delay) (%)		
6	canceled trucks (with no delay) (%)		
6	canceled cars (with delay) (%/min)	3.0%	
6	canceled trucks (with delay) (%/min)	1.0%	

- For capacity > (threshold capacity for decreases to design demand), then (actual demand) = (design demand) .
- For periods with capacity ≤ (threshold capacity for decreases to design demand), then (decrease variables) = (threshold variables).
- In this example, [canceled cars with delay)] = 0 for periods with capacity > 1400 V/hr, and [canceled cars with delay)] = 3.0% per minute of delay for periods with capacity ≤ 1400 V/hr.

Case 3: Input values for both threshold and range capacity:

DECREASE TO DEMAND		threshold	range
2	capacity for decreases to design demand (V/hr)	1400	1000
6	canceled cars (with no delay) (%)		
6	canceled trucks (with no delay) (%)		
6	canceled cars (with delay) (%/min)	3.0%	4.0%
6	canceled trucks (with delay) (%/min)	1.0%	2.0%

- For capacity > (threshold capacity for decreases to design demand), then (actual demand) = (design demand).
- For periods with capacity = (threshold capacity for decreases to design demand), then (decrease values) = (threshold values).
- For periods with capacity = (range capacity for decreases to design demand), then (decrease values) = (range values).
- For all other periods with capacity ≤ (threshold capacity for decreases to design demand), then (decrease values) are interpolated based on threshold and range capacities.
- In this example, (actual demand) = (design demand) for capacity > 1400 V/hr. [canceled cars (with delay)] = 3.0% per minute of delay for periods with capacity = 1400 V/hr, and [canceled cars (with delay)] = 4.0% per minute of delay for periods with capacity = 1000 V/hr. For periods with capacity = 1300 V/hr, interpolation produces [canceled cars (with delay)] = 4.0 – (4.0 – 3.0) * [(1300 – 1000) / (1400 – 1000)] = 4.0 – (1.0) * [300 / 400] = 3.3% per minute of delay.

We generally wait to estimate values for demand decreases until after we have calculated vehicle travel and user cost as described in Sec. 1.5.1.7, because the calculated values help us understand the distance and user cost tradeoffs that drivers will face as they decide whether to divert or cancel trips, instead of driving through the work zone.

1.5.1.9 Other User Cost Input

OTHER USER COST INPUT	cars	trucks	
other user cost per vehicle ($/V)	$0.00	$0.00	default
user cost per diversion ($/V)	$1.53	$2.93	

We can record and document here any additional user cost per vehicle of actual demand. In addition, user cost per diversion has been calculated and shown here, in parallel with the format in the Traffic Sheet.

1.5.2 ROUTES SHEET (ROUTES TAB)

1.5.2.1 General

The Routes Sheet provides a spreadsheet to calculate equivalent properties of normal and diversion routes that consist of more than one road or speed. Inputs that are unique to the Routes Sheet are briefly described here. A more detailed description of the Routes Sheet and its calculations is contained in Chapter 3 on Work Zone Route Calculations. The Routes Sheet also calculates work zone and diversion travel times, delays, and user cost per vehicle, in the same manner as the Input Sheet and the internal calculations of the Traffic Sheet. Inputs for those calculations are described above in Sec. 1.5.1. The Routes Sheet is not needed for projects that do not have complex routes, so if this is your first time using CO^3, skip this section and go on to Sec. 1.5.3.

Fig. 1-4 shows an example of a complex routing that includes two diversion routes, for which we estimate 40% of diverting vehicles will take Second Street and 60 % will take First Street. Fig. 1-5 shows an example of the Routes Sheet for this example. Inputs to the Routes Sheet are shown in color on a computer monitor and in light gray here. The purpose of this example is to show the variety of possible inputs. Do not try to follow this example closely here; it is explained in Sec. 3.1.4.4 Two Unequal Diversion Paths, Unequal Speeds, pg. 3-6.

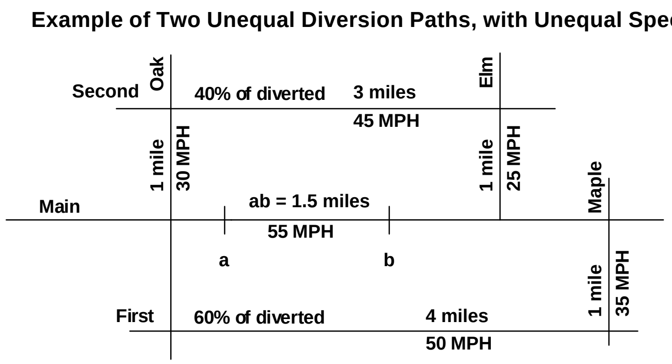


Fig. 1-4 Map of Example Routes

The general steps for using the Routes Sheet are the following:

1. Identify the work zone and diversion routes and estimate their distances, speeds, and fraction of traffic on each.
2. Input values into the “Route Distance, Speed, and Time” table.
3. Click F9 to calculate values for this table.
4. If we wish to also calculate vehicle user costs on the Route Sheet, we input values from this table to the “Route User Costs” table and click F9 to calculate these values.

1.5.2.2 Traffic Traveling Different Distances and Speeds

For complex routes, the Routes Sheet calculates equivalent travel distance, speed, time based on the following general equations for average distance traveled per vehicle, L_{avg}; average speed traveled per mile, S_{avg}; and average time taken per vehicle, T_{avg},

$$L_{avg} = \frac{total\ distance\ traveled}{total\ number\ of\ vehicles} = \frac{\sum_i V_i L_i}{\sum_i V_i} \tag{16}$$

$$S_{avg} = \frac{total\ distance\ traveled}{total\ time\ taken} = \frac{\sum_i V_i L_i}{\sum_i V_i \frac{L_i}{S_i}} \tag{17}$$

$$T_{avg} = \frac{total\ time\ taken}{total\ number\ of\ vehicles} = \frac{\sum_i V_i \frac{L_i}{S_i}}{\sum_i V_i} = \frac{L_{avg}}{S_{avg}} \tag{18}$$

where V_i = number of vehicles traveling distance L_i at speed S_i. These equations must be used to model a batch of vehicles consisting of different numbers traveling different distances at different speeds. The average distance and average speed can be used for any method or normal distance and speed.

ROUTE CALCULATIONS

Project: Main St. Reconstruction
By: J. Doe, 11/6/96
Other:

ROUTE USER COSTS

VEHICLE INPUT	cars	trucks
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00

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ROUTE TITLES		Combination		First St.		Second St.			
DISTANCE AND SPEED INPUT	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	1.5	see delay	1.5	see delay	1.5	see delay		see delay
	normal travel	1.5	55	1.5	55	1.5	55		
diversion	method travel	5.6	40.29	6.0	43.37	5.0	36		
	normal travel	3.6	55	4.0	55	3.0	55		
SPEED DELAY INPUT		threshold	range	threshold	range	threshold	range	threshold	range
capacity for speed delay (V/hr)		1500		1500		1500			
speed (when D~0) (mph)		45		45		45			
speed (when D=C) (mph)		25		25		25			
WORK ZONE TRAVEL									
zone normal travel time (min)		1.64		1.64		1.64			
zone method travel time (when D~0) (min)		2.00		2.00		2.00			
speed delay (when D~0) (min)		0.36		0.36		0.36			
zone method travel time (when D=C) (min)		3.60		3.60		3.60			
speed delay (when D=C) (min)		1.96		1.96		1.96			
WORK ZONE SPEED DELAY USER COST		threshold	range	threshold	range	threshold	range	threshold	range
car speed delay user cost (when D~0)		$0.07		$0.07		$0.07			
truck speed delay user cost (when D~0)		$0.07		$0.07		$0.07			
car speed delay user cost (when D=C)		$0.35		$0.35		$0.35			
truck speed delay user cost (when D=C)		$0.35		$0.35		$0.35			
DIVERSION TRAVEL									
diversion method travel time (min)		8.34		8.30		8.40			
diversion normal travel time (min)		3.93		4.36		3.27			
diversion delay (min)		4.41		3.94		5.13			
extra diversion travel distance (mi)		2.0		2.0		2.0			
DIVERSION USER COST		cars	trucks	cars	trucks	cars	trucks	cars	trucks
diversion delay user cost		$0.79	$0.79	$0.71	$0.71	$0.92	$0.92		
diversion distance user cost		$0.60	$2.00	$0.60	$2.00	$0.60	$2.00		
diversion user cost		$1.39	$2.79	$1.31	$2.71	$1.52	$2.92		
backup delay balance (min)		5.79	13.57	5.31	13.09	6.50	14.29		

ROUTE DISTANCE, SPEED, AND TIME

Route Title: Combination - Diversion Travel

Normal Travel							Method Travel						
Input				Calculated Values			Input				Calculated Values		
Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)	Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)
Main	40%	3	55	3.27	1.2	1.31	N. Oak	40%	1	30	2.00	0.4	0.80
Main	60%	4	55	4.36	2.4	2.62	Second	40%	3	45	4.00	1.2	1.60
							Elm	40%	1	25	2.40	0.4	0.96
							S. Oak	60%	1	30	2.00	0.6	1.20
							First	60%	4	50	4.80	2.4	2.88
							Maple	60%	1	40	1.50	0.6	0.90
Totals	1.00				3.60	3.93	Totals	3.00				5.60	8.34
Averages		3.60	55.00	3.93			Averages		5.60	40.29	8.34		
							Differences		2.00	-14.71	4.41		

ROUTE DISTANCE, SPEED, AND TIME

Route Title: First St. - Diversion Travel

Normal Travel							Method Travel						
Input				Calculated Values			Input				Calculated Values		
Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)	Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)
Main	100%	4	55	4.36	4	4.36	S. Oak	100%	1	30	2.00	1	2.00
							First	100%	4	50	4.80	4	4.80
							Maple	100%	1	40	1.50	1	1.50
Totals	1.00				4.00	4.36	Totals	3.00				6.00	8.30
Averages		4.00	55.00	4.36			Averages		6.00	43.37	8.30		
							Differences		2.00	-11.63	3.94		

ROUTE DISTANCE, SPEED, AND TIME

Route Title: Second St. - Diversion Travel

Normal Travel							Method Travel						
Input				Calculated Values			Input				Calculated Values		
Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)	Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)
Main	100%	3	55	3.27	3	3.27	N. Oak	100%	1	30	2.00	1	2.00
							Second	100%	3	45	4.00	3	4.00
							Elm	100%	1	25	2.40	1	2.40
Totals	1.00				3.00	3.27	Totals	3.00				5.00	8.40
Averages		3.00	55.00	3.27			Averages		5.00	35.71	8.40		
							Differences		2.00	-19.29	5.13		

Fig. 1-5 Routes Sheet

1.5.2.3 Route Distance, Speed, and Time Table (Route Travel)

We input and the Route Distance, Speed, and Time Table (also called Route Travel for short) calculates the equivalent travel values for normal travel and for method travel independent of each other. The Route Travel table also calculates the difference between them. We use the Route Travel Table, as necessary, for both work zone travel and diversion travel values. For each element of each route or road, we enter its name (to identify it) and distance and the fraction and average speed of traffic that will take it. For example, Fig. 1-4 has two routes of diversion normal travel and diversion method travel, First St. and Second St., for which we estimate 60% of traffic that diverts will travel First St. and 40% will travel Second St. when Main St. is under construction. Fig. 1-5 shows route distance, speed, and time input and output for each route, including the equivalent values for our estimated combination of First St. and Second St.

- Combination: 60% First St. and 40% Second St. Input: See Fig. 1-5. Output: diversion method travel distance = 5.6 mi, diversion method travel speed = 40.29 mph, and diversion method travel time = 8.34 min. This differs from diversion normal travel by +2.00 mi, –14.71 mph, and +4.41 min.
- First St.: Input: diversion normal travel = Main (4 mi @ 55 mph); diversion method travel = S. Oak (1 mi @ 30 mph), First (4 mi @ 50 mph), and Maple (1 mi @ 35 mph). Output: diversion method travel distance = 6.0 mi, diversion method travel speed = 43.37 mph, and diversion method travel time = 8.30 min.
- Second St.: Input: diversion normal travel = Main (3 mi @ 55 mph). diversion method travel = N. Oak (1 mi @ 30 mph), Second (3 mi @ 45 mph), and Elm (1 mi @ 25 mph). Output: diversion method travel distance = 5.0 mi, diversion method travel speed = 35.71 mph, and diversion method travel time = 8.40 min.

The Route Travel table calculates the weighted average of distance and travel time, from which it calculates the average speed of all vehicles under normal travel and method travel. In this example, we calculated equivalent values for diversion travel, but we did not calculate equivalent values for work zone travel, because work zone normal travel and work zone method travel both used a single 1.5 mi segment on Main St.

The Route Sheet includes only one Route Travel table. We often want to use more than one, as we did in Fig. 1-5. We can add tables by the following these steps:

1. L-click on the row numbers on the left side of the Route Travel table rows, to select all the rows of the Route Travel table.
2. Copy the rows of the Table.
3. L-click on a row number below the Route Travel table, then Paste (not Paste Value) the rows that were copied in Step 2.

1.5.2.4 Route User Costs

We input the equivalent normal travel and diversion travel into the Route User Costs table in the same way as in the Input Sheet, and CO^3 calculates the appropriate diversion travel and user cost values per vehicle. In its Route User Costs table, Fig. 1-5 has calculated the user costs for each of the three routes for which it calculated distance, speed, and time. In this example, work zone normal and method travel are not affected by the alternative routes. However, the

Route Distance, Speed, and Time table will calculate equivalent work zone normal and method travel values for more complex routes.

1.5.3 TRAFFIC SHEET

1.5.3.1 General

The CO^3 Program computes period and daily values of traffic congestion and user cost due to construction. The Traffic Sheet is our connection to CO^3 Program. Through the Traffic Sheet, we compute and report values for one direction of travel and one method of maintaining traffic in each computer run, which we call a CO^3 run.

As listed earlier in Sec. 1.4.2 C, the Traffic Sheet contains the following views or tables:

- The **Summary View** is the input form for the CO^3 Program, its buttons drive the CO^3 Program, and it summarizes CO^3 Program results for both directions of travel for up to four methods.
- The **Overall View** shows input and provides detailed output of CO^3 Program results for all variables for the latest CO^3 run. Therefore, it shows detailed information for one direction of travel using one traffic maintenance method. It shows all information in all the views for the latest CO^3 run.
- The **Traffic View** parallels the Overall View for the latest CO^3 run. It shows input and provides a traffic subset of CO^3 Program results for one direction of travel using one method.
- The **User Cost View** is like the Traffic View, except it reports a user cost subset of results.
- The **Combination View** or Combo View is like the Traffic View and User Cost view, except it reports a subset of their results.

The Traffic Sheet is the heart of CO^3, because here we perform primary input of data, calculate traffic congestion and user cost values, and report results. The Summary View is the core of the Traffic Sheet, because it is the only place that we input data in the Traffic Sheet, and it reports input values and a summary of output values that provides the key information from which we make decisions. Next in importance is the Overall View, because it reports each period's traffic impact and user cost. The other views are included to provide alternative formats for reporting selected output.

1.5.3.2 Summary View

1.5.3.2.1 General

As stated above, the Summary View is the core of CO^3. Not only is it the place that we input and calculate traffic impact and user cost, but it is the primary report on which we document input and output and from which we make decisions. The Summary View consists of the following elements, each of which is appropriately labeled in the view for easy identification:

- Input
  - For the project as a whole
    - Title block
    - Period length and traffic growth
    - Vehicle input

        - Period input: historical demand for each period in each direction
    - For each traffic direction and maintenance method
        - Method input
        - Distance and speed
        - Speed delay
        - Decrease to demand
        - Other user cost
        - Period input: capacity in each direction
- Control buttons
    - Navigation buttons, which take us to various locations in views
    - Action buttons, which direct CO^3 to perform specific calculations or to print reports.
- Output values
    - Design demand in each direction
    - Summary output of traffic impact and user cost

We generally use the Summary View in this same sequence. We input project information, we input method information, we calculate traffic delay and user cost values for each method, we move from one view to another to review results, and we print Summary View and/or other view(s) to document input and report results.

Here, as in other sheets, input cells (and often main headings for input) are indicated by a pale yellow background on the computer model and light gray background in this User's Manual and in black and white output. Delays and user cost are calculated from input cells (cells with pale yellow background) found in the Summary View. Input cells may have one of three types of values: numerical, text, or "blank." The numerical values provide the basis of all calculations and are limited to non-negative, decimal numbers. The text values (e.g., "SE", "7A", and "7A-5P") provide descriptive information only (e.g., a description of a method). Thus, they have no effect on the outcomes of calculations. An input cell left empty does not necessarily imply a value of zero in certain calculations.[3] (For example, for range inputs for speed delay and decrease in demand, a "blank," indicates that no interpolation/ extrapolation step will be performed. A numerical value of 0.0 causes the model to interpolate using 0.0 as the second point.) Therefore, the user should input zero when input is known to be zero, and leaving a cell blank when a zero should have been input can produce incorrect results. Input cells require values by keyboard entry in the case of numerical and text values, or by acceptance of a default value.

The input data from the Input Sheet, which were shown in shaded cells, are also input to the Summary View, either as project input or for one or more methods. Most values calculated in the Input Sheet are not shown in the Summary View. This is part of what makes the Input Sheet useful, because it provides information that would not otherwise be known.

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[3] In some instances, the spreadsheet may show a "blank" for some values, when the correct value is 0. This happens particularly for *speed delay* = 0 and *speed delay user cost* = 0, when *work zone normal travel speed* = *threshold speed* (*when D » 0*). The "blank" in place of zero occurs when the spreadsheet is configured to show zero as "blank." To change this, with your mouse click on "Tools" in the toolbar at the top of the spreadsheet. In the "Tools" menu that results, click "Options." In the "Options" window that results, click "View." In the "View" window that results, click "Zero values" such that it shows a check mark (✓) to its left. Then click on "OK." This will make the spreadsheet show zero, rather than showing zero as "blank."

Data are entered into the Summary View in three ways: (1) retaining default or other values already entered, (2) directly entering values, and (3) copying and pasting values from other cells. Of most concern is that the integrity of the CO^3 runs not be disturbed. Therefore, we never input anything except to the cells shown as input cells by their color. We also do not generally want to disturb formatting in cells. Also it is best to paste only the values of the data from other cells, not the cells' formatting or formulas. Therefore, when we paste, we Paste Values, which is a special way of pasting. This can be done in any of three ways. First, we go to the cell in which we want to Paste Value. Then to Paste Value: we (1) select the cell(s) in which to Paste Value the desired data by clicking on the upper left cell, and (2) either (a) click the Paste Value icon on the toolbar or (b) click the Paste Values icon **Paste Values** on the worksheet (where available) or (c) click on Edit on the toolbar, click Paste Special on its foldout menu, click Values and then OK on the Paste Special window.

The sections below will describe each component of the Summary View. For clarity, a figure representing the section of the Summary View being discussed is located at the top of each section.

1.5.3.2.2 Project Input: Title Block

PROJECT INFORMATION		REPORT INFORMATION	
PROJECT TITLE	US 00 Overlay Example Problem	REPORT TITLE	DETAILED USER COST REPORT SUMMARY VIEW
C.S. JOB # START DATE	90000 00000 6/00/98	DIVISION REPORT BY REPORT DATE	 R. I. Carr 1/2/97
NOTES:			

We enter project and report information to identify the Department project we are evaluating. The project and report information section is located at the top of each view. Like all input, we input project and report information into the Summary View and it is automatically placed in all views and printed in all reports from the Traffic Sheet. Project information includes: project title, job number, control section, and starting date. Report information includes: report title, Department division, name of user, and date of report. Space for additional notes is provided below the project and report information sections.

1.5.3.2.3 Project Input: Period Length and Traffic Growth

period length (min)	60
annual traffic growth (%)	5.00%
years of growth	2

The modeling duration time is divided into twenty-four periods. The maximum **period length** is 60 minutes, therefore the maximum modeling duration is 24 hr = 1 day. Period length is limited to 60, 30, 15, or 10 min (Default = 60 min). Use of a period length other than the default of 60 will result in a shorter modeling duration. For example, a duration of 30 minutes will produce modeling duration = (24 periods) * (30 min) = 12 hr. Period length is located to the left of the project information section located at the top of the Summary View.

Years of growth and percent annual traffic growth are parameters used in calculating design demand. Years of growth is the number of years between the date the historical traffic count was made and the date of the construction project we are modeling. For example, if the model is being run during 1997 for a project to be performed in 1999 using traffic count data obtained in 1994, years of growth = 1999 – 1994 = 5 yr. These data are input below the period length input to the left of the project information. Annual traffic growth, of course, is always an estimate. However, we should not just assume annual traffic growth = 0 or leave the input cell blank, unless our best estimate is, in fact, that the correct value is zero.

1.5.3.2.4 Vehicle Input

VEHICLE INPUT	cars	trucks
design demand (%)	90.0%	10.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation,($/V)	$1.00	$2.00

These data were described in Sec. 1.5.1.3 for the Input Sheet. We can directly Copy and Paste Value the values from an appropriate Input Sheet, using the Paste Values icon on the Excel toolbar or using the Paste Values **Paste Values** button on the Summary View.

1.5.3.2.5 Method Input

METHOD INPUT	METHOD 1	METHOD 2	METHOD 3	METHOD 4
method title	7A-5P	7A-5P, Publicity	7A-3P, Publicity	Night, 8P-6A

In method Input we enter a very brief description of each method of maintaining traffic that we are modeling, to distinguish its input and output from that of other methods of maintaining traffic. We usually select a title that distinguishes some particular feature, accompanied with the hours of the day the traffic will be maintained (e.g., a lane will be closed). For example, if Method 1 is to close one lane from 7:00 am to 5:00 pm, an appropriate title is 7A-5P, because these are the hours that the lane is closed due to construction. This provides easy identification for future reference. Method 1 is generally the most common way to undertake the construction activity. A method title is generally more specific that the title used in an Input Sheet, because the Input Sheet does not include any period input, and its method is generally not particularly sensitive to the hours that traffic is maintained.

1.5.3.2.6 Distance and Speed, Speed Delay, Decrease to Demand, and Other User Cost Input

METHOD INPUT		METHOD 1		METHOD 2		METHOD 3		METHOD 4	
	method title	7A-5P		7A-5P, Publicity		7A-3P, Publicity		Night, 8P-6A	
DISTANCE AND SPEED	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	2.0	see delay	2.0	see delay	2.0	see delay	2.0	see delay
	normal travel	2.0	65	2.0	65	2.0	65	2.0	65
diversion	method travel	12.0	50	12.0	50	12.0	50	12.0	50
	normal travel	10.0	65	10.0	65	10.0	65	10.0	65
SPEED DELAY		threshold	range	threshold	range	threshold	range	threshold	range
capacity for speed delay (V/period)		1400		1400		1400		1400	
speed (when D~0) (mph)		45		45		45		45	
speed (when D=C) (mph)		10		10		10		10	
DECREASE TO DEMAND		threshold	range	threshold	range	threshold	range	threshold	range
capacity for decreases to design demand (V/period)		1400		1400		1400		1400	
canceled cars (with no delay) (%)		5.0%							
canceled trucks (with no delay) (%)									
canceled cars (with delay) (%/min)		1.0%		3.0%		3.0%		1.0%	
canceled trucks (with delay) (%/min)				1.0%		1.0%			
diverted cars (with no delay) (%)		5.0%							
diverted trucks (with no delay) (%)									
diverted cars (with delay) (%/min)		1.0%		3.0%		3.0%		1.0%	
diverted trucks (with delay) (%/min)		0.5%		1.0%		1.0%		0.5%	

These input data are required for each traffic maintenance method we are modeling (e.g., close one lane from 7:00 am to 5:00 pm). These data were described in Sec. 1.5.1.3, 1.5.1.5, 1.5.1.6, 1.5.1.8, and 1.5.1.9 for the Input Sheet. Each input is for a particular construction method. Inputs are for both directions of travel unless otherwise specified. As previously mentioned, each Traffic Sheet can analyze up to four different traffic maintenance methods. We can directly copy the values from an appropriate Input Sheet, using Copy and either clicking the Paste Values icon on the Excel toolbar or clicking the Paste Values **Paste Values** button on the Summary View.

1.5.3.2.7 Period Input

METHOD INPUT	METHOD 1	METHOD 2	METHOD 3	METHOD 4
method title	7A-5P	7A-5P, Publicity	7A-3P, Publicity	Night, 8P-6A

==

PERIOD INPUT			backup at start (V)		0	0	0	0	0	0	0	0
direction	SE	NW	SE	NW	SE	NW	SE	NW	SE	NW	SE	NW
period	historical demand		design demand		capacity		capacity		capacity		capacity	
(hr)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)
12 A	436	416	481	459	3400	3400	3400	3400	3400	3400	1400	1400
1 A	252	280	278	309	3400	3400	3400	3400	3400	3400	1400	1400
2 A	195	152	215	168	3400	3400	3400	3400	3400	3400	1400	1400
3 A	76	118	84	130	3400	3400	3400	3400	3400	3400	1400	1400
4 A	81	127	89	140	3400	3400	3400	3400	3400	3400	1400	1400
5 A	133	151	147	166	3400	3400	3400	3400	3400	3400	1400	1400
6 A	431	557	475	614	3400	3400	3400	3400	3400	3400	3400	3400
7 A	1280	1530	1411	1687	1400	1400	1400	1400	1400	1400	3400	3400
8 A	1681	2445	1853	2696	1400	1400	1400	1400	1400	1400	3400	3400
9 A	1401	1658	1545	1828	1400	1400	1400	1400	1400	1400	3400	3400
10 A	1473	1486	1624	1638	1400	1400	1400	1400	1400	1400	3400	3400
11 A	1697	1607	1871	1772	1400	1400	1400	1400	1400	1400	3400	3400
12 P	1835	1958	2023	2159	1400	1400	1400	1400	1400	1400	3400	3400
1 P	1735	1820	1913	2007	1400	1400	1400	1400	1400	1400	3400	3400
2 P	1810	1903	1996	2098	1400	1400	1400	1400	1400	1400	3400	3400
3 P	2211	1722	2438	1899	1400	1400	1400	1400	3400	3400	3400	3400
4 P	2482	2111	2736	2327	1400	1400	1400	1400	3400	3400	3400	3400
5 P	2606	2303	2873	2539	3400	3400	3400	3400	3400	3400	3400	3400
6 P	1965	1857	2166	2047	3400	3400	3400	3400	3400	3400	3400	3400
7 P	1422	1335	1568	1472	3400	3400	3400	3400	3400	3400	3400	3400
8 P	1238	1113	1365	1227	3400	3400	3400	3400	3400	3400	1400	1400
9 P	1162	1091	1281	1203	3400	3400	3400	3400	3400	3400	1400	1400
10 P	825	867	910	956	3400	3400	3400	3400	3400	3400	1400	1400
11 P	607	570	669	628	3400	3400	3400	3400	3400	3400	1400	1400
Total	29034	29177	32010	32168	61600	61600	61600	61600	65600	65600	61600	61600

The starting time of each **period** is input in sequence into the column under the Period Input heading, “period, (hr).” The first period in the column, which is 12A (midnight) in this example, is the period at which CO^3 starts its traffic modeling. We prefer to start the model at a period that has no initial traffic backup. Therefore, we want the first period to have a capacity that is enough greater than demand (i.e., light traffic and maximum capacity) that it will have no backup. This avoids “carrying over” remaining backups from the end of one modeling duration to the start of the next. Default = 12A for daytime closure and for 24 hr closure.

Backup at start (V) is the number of vehicles backed up at the start of the first period being modeled (12A in this example). We input a value for backup at start if modeling is started at a period that is preceded by backup; otherwise, we leave it blank. Backup at start most typically occurs when we model periods of less than 60 min, in which case we cannot model an entire 24 hour cycle on one Traffic Sheet. For example, modeling 15-min periods for 6A to 6P = 12 hours requires 24 periods of 15 min from 6A to 12P on one Traffic Sheet and 24 periods from 12N to 6P on another Traffic Sheet. If the 6A to 12P model calculates backup at 12N = 45 V, then we enter backup at start = 45 V for the 12P to 6P model Traffic Sheet.

SummaryView

Copy This Sheet	period length (min)	60	
Update	annual traffic growth (%)	5.00%	
	years of growth	2	
VEHICLE INPUT		cars	trucks
	design demand (%)	90.0%	10.0%
	user cost per hour ($/V hr)	$10.79	$10.79
	user cost per mile, ($/V mi)	$0.30	$1.00
	user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION		
PROJECT TITLE	US 00 Overlay	
	Example Problem	
Paste Values	C.S.	90000
	JOB #	00000
	START DATE	6/00/98

REPORT INFORMATION	
REPORT TITLE	DETAILED USER COST REPORT
	SUMMARY VIEW
DIVISION	
REPORT BY	R. I. Carr
REPORT DATE	1/2/97

NOTES:

METHOD INPUT		METHOD 1		METHOD 2		METHOD 3		METHOD 4	
	method title	7A-5P		7A-5P, Publicity		7A-3P, Publicity		Night, 8P-6A	
DISTANCE AND SPEED	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	2.0	see delay	2.0	see delay	2.0	see delay	2.0	see delay
	normal travel	2.0	65	2.0	65	2.0	65	2.0	65
diversion	method travel	12.0	50	12.0	50	12.0	50	12.0	50
	normal travel	10.0	65	10.0	65	10.0	65	10.0	65
SPEED DELAY		threshold	range	threshold	range	threshold	range	threshold	range
	capacity for speed delay (V/period)	1400		1400		1400		1400	
	speed (when D~0) (mph)	45		45		45		45	
	speed (when D=C) (mph)	10		10		10		10	
DECREASE TO DEMAND		threshold	range	threshold	range	threshold	range	threshold	range
	capacity for decreases to design demand (V/period)	1400		1400		1400		1400	
	canceled cars (with no delay) (%)	5.0%							
	canceled trucks (with no delay) (%)								
	canceled cars (with delay) (%/min)	1.0%		3.0%		3.0%		1.0%	
	canceled trucks (with delay) (%/min)			1.0%		1.0%			
	diverted cars (with no delay) (%)	5.0%							
	diverted trucks (with no delay) (%)								
	diverted cars (with delay) (%/min)	1.0%		3.0%		3.0%		1.0%	
	diverted trucks (with delay) (%/min)	0.5%		1.0%		1.0%		0.5%	
OTHER USER COST INPUT	Update	cars	trucks	cars	trucks	cars	trucks	cars	trucks
	other user cost per actual demand ($/V)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	user cost per diversion ($/V)	$1.53	$2.93	$1.53	$2.93	$1.53	$2.93	$1.53	$2.93
	Paste Values	Calculate	Calculate	Calculate	Calculate	Calculate	Calculate	Calculate	Calculate

Summary | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

PERIOD INPUT				backup at start (V)	0	0	0	0	0	0	0	0
direction	SE	NW	SE	NW	SE	NW	SE	NW	SE	NW	SE	NW
period	historical demand		design demand		capacity		capacity		capacity		capacity	
(hr)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)
12 A	436	416	481	459	3400	3400	3400	3400	3400	3400	1400	1400
1 A	252	280	278	309	3400	3400	3400	3400	3400	3400	1400	1400
2 A	195	152	215	168	3400	3400	3400	3400	3400	3400	1400	1400
3 A	76	118	84	130	3400	3400	3400	3400	3400	3400	1400	1400
4 A	81	127	89	140	3400	3400	3400	3400	3400	3400	1400	1400
5 A	133	151	147	166	3400	3400	3400	3400	3400	3400	1400	1400
6 A	431	557	475	614	3400	3400	3400	3400	3400	3400	3400	3400
7 A	1280	1530	1411	1687	1400	1400	1400	1400	1400	1400	3400	3400
8 A	1681	2445	1853	2696	1400	1400	1400	1400	1400	1400	3400	3400
9 A	1401	1658	1545	1828	1400	1400	1400	1400	1400	1400	3400	3400
10 A	1473	1486	1624	1638	1400	1400	1400	1400	1400	1400	3400	3400
11 A	1697	1607	1871	1772	1400	1400	1400	1400	1400	1400	3400	3400
12 P	1835	1958	2023	2159	1400	1400	1400	1400	1400	1400	3400	3400
1 P	1735	1820	1913	2007	1400	1400	1400	1400	1400	1400	3400	3400
2 P	1810	1903	1996	2098	1400	1400	1400	1400	1400	1400	3400	3400
3 P	2211	1722	2438	1899	1400	1400	1400	1400	3400	3400	3400	3400
4 P	2482	2111	2736	2327	1400	1400	1400	1400	3400	3400	3400	3400
5 P	2606	2303	2873	2539	3400	3400	3400	3400	3400	3400	3400	3400
6 P	1965	1857	2166	2047	3400	3400	3400	3400	3400	3400	3400	3400
7 P	1422	1335	1568	1472	3400	3400	3400	3400	3400	3400	3400	3400
8 P	1238	1113	1365	1227	3400	3400	3400	3400	3400	3400	1400	1400
9 P	1162	1091	1281	1203	3400	3400	3400	3400	3400	3400	1400	1400
10 P	825	867	910	956	3400	3400	3400	3400	3400	3400	1400	1400
11 P	607	570	669	628	3400	3400	3400	3400	3400	3400	1400	1400
Total	29034	29177	32010	32168	61600	61600	61600	61600	65600	65600	61600	61600

SUMMARY OUTPUT	traffic method	7A-5P		7A-5P, Publicity		7A-3P, publicity		night, 8P-6A	
	direction	SE	NW	SE	NW	SE	NW	SE	NW
	total user cost	$35,433	$37,919	$25,250	$26,599	$17,712	$20,876	$4,818	$4,275
	user cost of delays	$27,903	$29,737	$14,828	$15,560	$10,680	$12,241	$4,183	$3,720
	user cost of decreases	$7,530	$8,183	$10,421	$11,039	$7,032	$8,635	$634	$556
	maximum backup (V)	347	264	0	0	0	0	0	0
	maximum backup length (lane mi)	2.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
copy these values into Impact Sheet	maximum delay (min.)	23.5	21.5	9.3	9.2	7.5	9.2	7.4	6.4
	average delay (min)	5.9	6.4	3.4	3.6	2.2	2.7	0.7	0.7
	total delay, except diversions (V hr)	2586	2756	1374	1442	990	1134	388	345
	total vehicles canceled(V)	2850	3094	3985	4221	2689	3302	236	207
	total vehicles diverted (V)	2960	3216	3985	4221	2689	3302	249	218
	total decrease in demand (V)	5809	6310	7970	8442	5378	6604	484	424
	% decrease in demand	18.1%	19.6%	24.9%	26.2%	16.8%	20.5%	1.5%	1.3%
	delay per diverted vehicle (min)	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
	total diversion delay (V hr)	255	277	343	364	232	284	21	19
	average delay, including diversions (min)	5.8	6.3	3.7	3.9	2.5	2.9	0.8	0.7
	total delay, including diversions (V hr)	2841	3033	1718	1806	1221	1419	409	363
	user cost / design demand ($/V)	$1.11	$1.18	$0.79	$0.83	$0.55	$0.65	$0.15	$0.13
	delay cost / actual demand ($/V)	$1.06	$1.15	$0.62	$0.66	$0.40	$0.48	$0.13	$0.12
Auto: ON Print: ON Now: OK	validity of output	VALID	VALID	VALID	VALID	VALID	VALID	VALID	VALID

Fig. 1-6 Summary View

Direction of traffic flow and **historical** traffic **demand** are required input to calculate design demand and actual demand. Traffic growth variables needed for calculation are the years of growth, percent annual traffic growth, and the percent of design demand that is trucks, which were discussed in Sec. 1.5.3.2.3 and 1.5.3.2.4. Historical demand is input in the Period Input section of the Summary View below the direction input location. CO^3 calculates **design demand** from

$$\text{design demand} = (\text{historical demand}) * \left[1 + (\text{annual traffic growth})\right]^{(\text{years of growth})} \qquad (19)$$

For example, 12A SE design demand = (436 Vph) * [1 + (5% = 0.05)]^2 = (436) * [1.1025] = 481 Vph. We can calculate design demand by clicking the cursor on the update button Update or by pressing the F9 key. The update button is located within the Other Cost Input heading.

Each period's **capacity** is the capacity of the method route during construction. For example, if one lane of a two-lane road will be closed from 7A to 5P on each day of construction, input capacity for the 10 periods from 7A to 5P is the estimated capacity of one lane during construction (1400 V/period in this example), and input capacity for the other 14 periods is the estimated capacity of two lanes on days when there is no construction (3400 V/period in this example).

1.5.3.2.8 Summary Output

METHOD INPUT	METHOD 1	METHOD 2	METHOD 3	METHOD 4
method title	7A-5P	7A-5P, Publicity	7A-3P, Publicity	Night, 8P-6A

SUMMARY OUTPUT traffic method	7A-5P		7A-5P, Publicity		7A-3P, Publicity		Night, 8P-6A	
direction	SE	NW	SE	NW	SE	NW	SE	NW
total user cost	$35,433	$37,919	$25,250	$26,599	$17,712	$20,876	$4,818	$4,275
user cost of delays	$27,903	$29,737	$14,828	$15,560	$10,680	$12,241	$4,183	$3,720
user cost of decreases	$7,530	$8,183	$10,421	$11,039	$7,032	$8,635	$634	$556
maximum backup (V)	347	264	0	0	0	0	0	0
maximum backup length (lane mi)	2.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
maximum delay (min.)	23.5	21.5	9.3	9.2	7.5	9.2	7.4	6.4
average delay (min)	5.9	6.4	3.4	3.6	2.2	2.7	0.7	0.7
total delay, except diversions (V hr)	2586	2756	1374	1442	990	1134	388	345
total vehicles canceled(V)	2850	3094	3985	4221	2689	3302	236	207
total vehicles diverted (V)	2960	3216	3985	4221	2689	3302	249	218
total decrease in demand (V)	5809	6310	7970	8442	5378	6604	484	424
% decrease in demand	18.1%	19.6%	24.9%	26.2%	16.8%	20.5%	1.5%	1.3%
delay per diverted vehicle (min)	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
total diversion delay (V hr)	255	277	343	364	232	284	21	19
average delay, including diversions (min)	5.8	6.3	3.7	3.9	2.5	2.9	0.8	0.7
total delay, including diversions (V hr)	2841	3033	1718	1806	1221	1419	409	363
user cost / design demand	$1.11	$1.18	$0.79	$0.83	$0.55	$0.65	$0.15	$0.13
delay cost / actual demand	$1.06	$1.15	$0.62	$0.66	$0.40	$0.48	$0.13	$0.12
Auto: ON Print: ON Now: OK validity of output	VALID	VALID	VALID	VALID	VALID	VALID	VALID	VALID

You can copy these values into impact sheet

Summary output provides a summary of the calculated results for each method. Complete results, including results for each period, are in the Overall View, which is described in Sec. 1.5.3.3 on page 1-34. The relationships among speed delay, backup delay, demand decrease, and actual demand and CO^3 calculations are described in Sec. 5.6, pg. 5-12

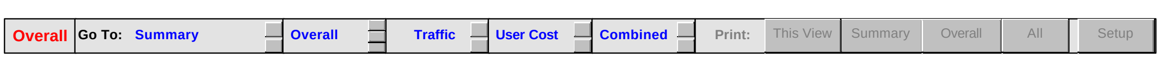
Summary output consists of the following:[4,5]

[4] demand decreases = cancelled and diverted vehicles
actual demand = design demand – demand decreases = vehicles that travel through the work zone (or detour).

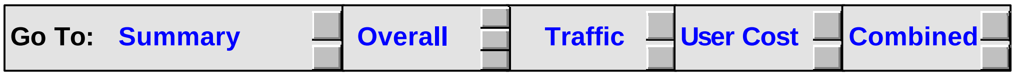
[5] Backup occurs when actual demand exceeds capacity, and vehicles must wait to enter the work zone. Backup delay (min) is the length of time between a vehicle's arrival at the backed-up queue and its reacing the front of the queue and entering the work zone.

- **total user cost** = all user cost = user cost of delays + user cost of decreases.
- **user cost of delays** = total user costs for speed delay and backup delay.
- **user cost of decreases** = total user costs for cancellations and diversions.
- **maximum backup (V)** = maximum number of vehicles that are backed up in any period. Calculations of backup are described in Sec. 5.5, pg. 5-10.
- **maximum backup length (lane mi)** = lane miles of backup due to maximum backup = (maximum backup) * (vehicle length in backup, default = 30').
- **maximum delay (min)** = maximum delay of any vehicle in actual demand = maximum sum of backup delay and speed delay of any vehicle.
- **average delay (min)** = average delay for vehicles in actual demand = (total delay, except diversions) / (total actual demand)
- **total delay, except diversions (V hr)** = speed delay and backup delay for vehicles in actual demand = total speed delay + total backup delay.
- **total vehicles canceled (V)** = total number of vehicles that cancel trips.
- **total vehicles diverted (V)** = total number of vehicles that divert around the work zone (or around detour).
- **total decrease in demand (V)** = (total vehicles canceled) + (total vehicles diverted) = (design demand) – (actual demand).
- **% decrease in demand** = fraction of design demand that cancels trips or diverts around work zone (or around detour) = (total decrease in demand) / (total design demand).
- **delay per diverted vehicle (min)** = delay time for each vehicle that diverts around work zone (or around detour).
- **total diversion delay (V hr)** = total delay time from diversions = (delay per diverted vehicle) * (total vehicles diverted) / (60 min/hr).
- **average delay, including diversions (min)** = average delay for vehicles that do not cancel = (total delay, including diversions) / [(actual demand) + (total vehicles diverted)].
- **total delay, including diversions (V hr)** = total delay for traffic through the work zone (or detour) and diversions = (total delay, except diversions) + (total diversion delay).
- **user cost / design demand** = average user cost for all normal traffic = (total user cost) / (design demand)
- **delay cost / actual demand** = average delay cost for vehicles in actual demand = (user cost of delays) / (actual demand).
- **validity of output** = a check on whether the summary output shown was computed from the input shown. VALID indicates summary output shown was computed using the input shown. NOT VALID indicates one or more input values have been changed since the current summary output was computed.

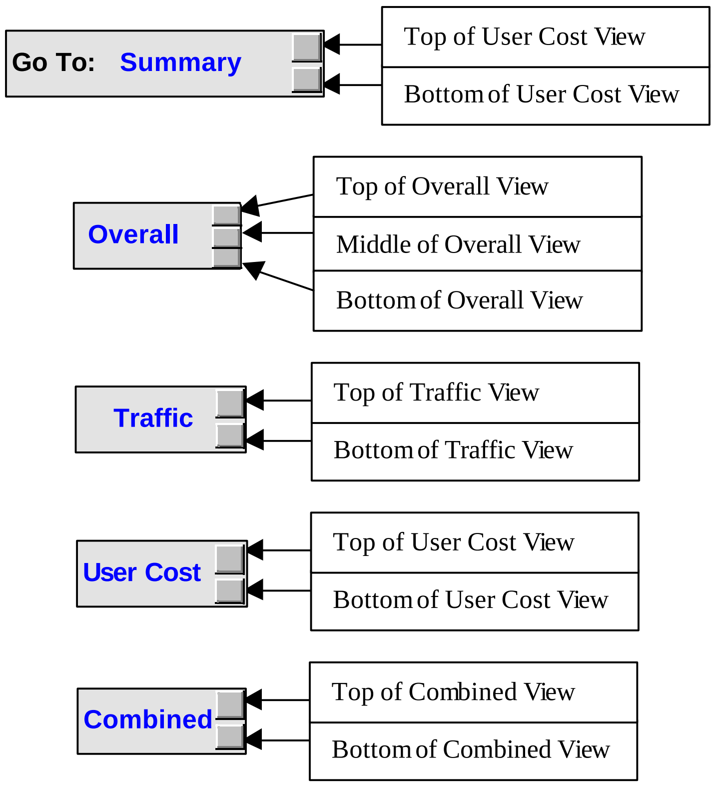
1.5.3.2.9 Sheet Navigation Buttons



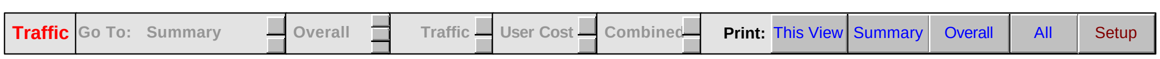
The standard button bar on each view (this button bar was copied from the Overall View) has a segment near its left end (enlarged below) on which we click to move to different views of the Traffic Sheet.



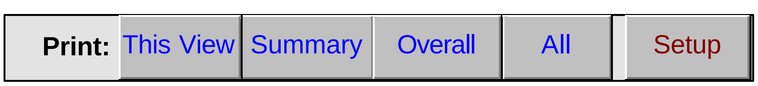
Using the mouse, we place the cursor over and L-click on a button to the right of the view to which we want to go. The CO^3 Program moves us to the appropriate view and position. The illustrations below indicate the destination of each button.



1.5.3.2.10 Action Buttons: Print View Buttons



The standard button bar (this bar was copied from the Traffic View) has a segment at its right end (enlarged below), on which we click buttons to print one or more views.



We click on a button to perform the following print actions:

- This View – Print the view that is on the screen, whose title is at the left end of the button bar.
- Summary – Print the Summary View.
- Overall – Print the Overall View.
- All – Print all five views: Summary View, Overall View, Traffic View, User Cost View, and Combined View.
- Setup – Reset print setup to the Traffic Sheet default. This can be used to override a print setup the user may have used for a special printing. It is rarely needed.

1.5.3.2.11 Action Buttons: Calculation Buttons

We click on calculation buttons to direct the CO^3 Program to perform calculations. The most important is the "Calculate" button [Calculate] in the column in each method and direction for which we have input data. By clicking a Calculate button in a method-direction column, we tell the CO^3 Program to perform a computer run to compute traffic impacts and user costs for the method and direction.

1.5.3.2.12 Action Buttons: Output Validation Buttons

METHOD INPUT	METHOD 1	METHOD 2	METHOD 3	METHOD 4
method title	7A-5P	7A-5P, Publicity	7A-3P, Publicity	Night, 8P-6A

===

Auto ON	Print: ON	Now: OK	validity of output	VALID	VALID	VALID	VALID	VALID	VALID	VALID	VALID

The CO^3 Program contains a validity check that determines whether the summary output shown matches the input values shown in the Summary View. It does this by determining if any input value has changed since the results shown in summary output were calculated. The validity check can be invoked in several ways, using the validation buttons located at the bottom left of the Summary View (and enlarged below), to the left of "validity of output" in the output summary.

There are three output validation buttons, which act as switches. Each is shown in its two positions below.

Auto: ON Print: ON Now: OK

Auto: OFF Print: OFF Now: NO

A value **validity of output = NOT VALID** indicates the output shown is based on input values of which at least one has changed. This tells us some input data has changed between the last CO^3 run and our viewing or printing the Summary View, and output is not valid. Validity status is shown on the computer screen and in printed reports in the following way:

- **Auto = ON** indicates the validity checker was on for all methods during the last CO^3 run. **Auto = OFF** indicates the validity checker may not have been on.
- **Print = ON** indicates the validity checker was on and was run when this view was printed. Therefore, when we see a printed Summary View that has Print = ON and validity of output = VALID, we know the output summary values are valid for the input shown. **Print = OFF** indicates the validity checker was not on when this view was printed.
- **Now = OK** indicates the validity checker was run at or since the last CO^3 run. It means nothing when Auto = ON. However, if Auto = OFF, then Now = OK would indicate a validity check had been run since the last CO^3 run. **Now = NO** (which can only occur in conjunction with Auto = OFF) indicates validity is not current: The Now button has not been pushed since the last computer run, and the validity checker was not on during the last computer run.

Fig. 1-7, Fig. 1-8, and Fig. 1-9 show the lower left corner of the Summary View for different settings of the output validation buttons. The summary output values for method “7A-5P, Publicity”, direction “SE” were computed using capacity at 9P = 3400. Note this has been changed to capacity at 9P = 2800 in each of the three figures, but the output has not been recomputed. Therefore, in all three of these figures, the summary output for method “7A-5P, Publicity”, direction “SE” does not match the input values in the Summary View, and the output is NOT VALID. The three other method/directions are VALID.

Use of the output validity buttons is described below, illustrated by the figures.

- **Auto button**:
  - Set Auto button to ON (default) to (1) immediately perform validity check on all methods and direction summary output and (2) automatically perform validity check on all methods and directions at the end of each computer run, which will set value of Now button to OK. Fig. 1-7 shows the change in color of column 3 summary output and “validity of output” = NOT VALID, when Auto = ON.
    - Valid output summary will be indicated on screen by “validity of output” = VALID.
    - Invalid output summary will be shown on screen in light red, printed in light gray, and “validity of output” = NOT VALID .
  - Set Auto button to OFF to prevent validity check at end of computer run. Output summary will not show validity of output, and Now button will be set to NO at end of each computer run. Fig. 1-8 shows results of Auto = OFF during the last computer run.
- **Print button**:
  - Set Print button to ON to automatically perform validity check on all methods and directions when Summary View is printed. Fig. 1-7 shows the change to gray of column 3 summary output and “validity of output” = NOT VALID in printed report, when Print = ON.
    - Valid output summary will be indicated on screen by “validity of output” = VALID.
    - Invalid output summary will be printed in light gray, and “validity of output” = NOT VALID .
  - Set Print button to OFF to turn off validity check when Summary View is printed. Summary View will be printed with “validity of output” = blank, as shown in Fig. 1-8.
- **Now button**: Click Now button to immediately perform validity check on all methods and directions. Value of Now button will be set to OK. Fig. 1-9 indicates the correct output validity, even though Auto = OFF and Print = OFF.
    - Valid output summary will be indicated on screen by “validity of output” = VALID.
    - Invalid output summary will be shown on the screen in red and printed in light gray, and “validity of output” = NOT VALID.

Auto = ON, Print = ON, Now = OK, and validity of output = VALID does not indicate that an output summary on the computer monitor is valid, because we or someone else may have changed an input value since the summary output was computed. However, we can easily check validity anytime by clicking the Now button. Print = ON and validity of output = VALID (regardless of the status of the Auto button or the Now button) in a printed Summary View always shows the output summary is valid, because these indicate a validity check was performed during the printing operation.

9 P	1162	1091	1281	1203	3400	3400	2800	3400
10 P	825	867	910	956	3400	3400	3400	3400
11 P	607	570	669	628	3400	3400	3400	3400
Total	29034	29177	32010	32168	61600	61600	61000	61600
SUMMARY OUTPUT				traffic method	7A-5P		7A-5P, Publicity	
				direction	SE	NW	SE	NW
total user cost					$35,433	$37,919	$25,250	$26,599
user cost of delays					$27,903	$29,737	$14,828	$15,560
user cost of decreases					$7,530	$8,183	$10,421	$11,039
maximum backup (V)					0	264	347	0
maximum backup length (lane mi)					0.0	1.5	2.0	0.0
maximum delay (min.)					9.3	21.5	23.5	9.2
average delay (min)					3.4	6.4	5.9	3.6
total delay, except diversions (V hr)					1374	2756	2586	1442
total vehicles canceled(V)					3985	3094	2850	4221
total vehicles diverted (V)					3985	3216	2960	4221
total decrease in demand (V)					7970	6310	5809	8442
% decrease in demand					18.1%	19.6%	24.9%	26.2%
delay per diverted vehicle (min)					5.2	5.2	5.2	5.2
total diversion delay (V hr)					343	277	255	364
average delay, including diversions (min)					3.4	6.3	6.3	3.9
total delay, including diversions (V hr)					1718	3033	2841	1806
user cost / design demand					$1.11	$1.18	$0.79	$0.83
delay cost / actual demand					$1.06	$1.15	$0.62	$0.66
Autc ON	Print ON	Nov OK		validity of output	VALID	VALID	NOT VALID	VALID

You can copy these values into impact sheet

Fig. 1-7 Screen and Print Output of Summary View with Output Validity Buttons in ON (Default) Positions

9 P	1162	1091	1281	1203	3400	3400	2800	3400
10 P	825	867	910	956	3400	3400	3400	3400
11 P	607	570	669	628	3400	3400	3400	3400
Total	29034	29177	32010	32168	61600	61600	61000	61600
SUMMARY OUTPUT				traffic method	7A-5P		7A-5P, Publicity	
				direction	SE	NW	SE	NW
total user cost					$35,433	$37,919	$25,250	$26,599
user cost of delays					$27,903	$29,737	$14,828	$15,560
user cost of decreases					$7,530	$8,183	$10,421	$11,039
maximum backup (V)					347	264	347	0
maximum backup length (lane mi)					2.0	1.5	2.0	0.0
maximum delay (min.)					23.5	21.5	23.5	9.2
average delay (min)					5.9	6.4	5.9	3.6
total delay, except diversions (V hr)					2586	2756	2586	1442
total vehicles canceled(V)					2850	3094	2850	4221
total vehicles diverted (V)					2960	3216	2960	4221
total decrease in demand (V)					5809	6310	5809	8442
% decrease in demand					18.1%	19.6%	24.9%	26.2%
delay per diverted vehicle (min)					5.2	5.2	5.2	5.2
total diversion delay (V hr)					255	277	255	364
average delay, including diversions (min)					5.8	6.3	6.3	3.9
total delay, including diversions (V hr)					2841	3033	2841	1806
user cost / design demand					$1.11	$1.18	$0.79	$0.83
delay cost / actual demand					$1.06	$1.15	$0.62	$0.66
Autc OFF	Print OFF	Nov NO		validity of output				

You can copy these values into impact sheet

Fig. 1-8 Print Output of Summary View with Print Button in OFF Position

9 P	1162	1091	1281	1203	3400	3400	2800	3400
10 P	825	867	910	956	3400	3400	3400	3400
11 P	607	570	669	628	3400	3400	3400	3400
Total	29034	29177	32010	32168	61600	61600	61000	61600
SUMMARY OUTPUT				traffic method	7A-5P		7A-5P, Publicity	
				direction	SE	NW	SE	NW
				total user cost	$35,433	$37,919	$25,250	$26,599
				user cost of delays	$27,903	$29,737	$14,828	$15,560
				user cost of decreases	$7,530	$8,183	$10,421	$11,039
				maximum backup (V)	347	264	347	0
				maximum backup length (lane mi)	2.0	1.5	2.0	0.0
You can copy these values into impact sheet				maximum delay (min.)	23.5	21.5	23.5	9.2
				average delay (min)	5.9	6.4	5.9	3.6
				total delay, except diversions (V hr)	2586	2756	2586	1442
				total vehicles canceled(V)	2850	3094	2850	4221
				total vehicles diverted (V)	2960	3216	2960	4221
				total decrease in demand (V)	5809	6310	5809	8442
				% decrease in demand	18.1%	19.6%	24.9%	26.2%
				delay per diverted vehicle (min)	5.2	5.2	5.2	5.2
				total diversion delay (V hr)	255	277	255	364
				average delay, including diversions (min)	5.8	6.3	6.3	3.9
				total delay, including diversions (V hr)	2841	3033	2841	1806
				user cost / design demand	$1.11	$1.18	$0.79	$0.83
				delay cost / actual demand	$1.06	$1.15	$0.62	$0.66
Auto OFF	Print OFF	Now OK		validity of output	VALID	VALID	NOT VALID	VALID

Fig. 1-9 On Screen Summary View with Auto = OFF and Now Button activated (= OK)

1.5.3.3 Overall View

1.5.3.3.1 General

The Overall View is second only to the Summary View in importance, because it alone shows the traffic impact and user cost results for each period for one method and direction. In addition, it shows the input data on which the results are based and summary output. Therefore, the Overall View provides a complete report of input values and the detailed and summarized output for the most recent computer run, as shown in its three major elements:

- Input shows complete input for project, vehicles, methods, and periods, as transferred from the Summary View, for one traffic maintenance direction and method.
- Period output provides computer results for demand, backup, delay, decreases in demand, and user cost for each of the 24 periods, with totals, maximums, and minimums, as appropriate.
- Summary output is the same as in the Summary View.

1.5.3.3.2 Period Output

- **capacity**, **historical demand**, and **design demand** were discussed in Sec. 1.5.3.2.7.
- **actual demand (V/period)** = number of vehicles that arrive during the period and pass through the work zone (or detour) = (design demand) – (decrease in demand) = (design demand) – [(canceled cars) + (canceled trucks) + (diverted cars) + (diverted trucks)].
- **backup eop (V)** = end of period backup = number of vehicles that is backed up at the end of the period and start of the next period = actual demand that has arrived in this period and previous periods that is waiting to enter the work zone (or detour) at the end of this period. Maximum backup for each period occurs either at its start or its end. Therefore, the maximum backup for each period is the larger of (1) its end of period backup and (2) the end of period backup of the previous period, both of which are shown in the backup eop column.
- **backup length eop (lane mile)** = end of period backup length = lane miles of backup at end of the period = length of backup eop = (backup eop) * (vehicle length in

backup, default = 30'). Like end of period backup, maximum backup length for each period occurs either at its start or its end. Therefore, the maximum backup lengths are shown in end of period backup length. Therefore, the maximum backup length for each period is the larger of (1) its end of period backup length and (2) the end of period backup length of the previous period, both of which are shown in the backup length eop column.

- **maximum delay (min)** = maximum delay of any vehicle in actual demand that arrived at the work zone during the period, which includes backup delay and speed delay. This does not include diversion delay of a vehicle, because diverted vehicles are not included in actual demand.
- **total period delay (V hr)** = speed delay and backup delay for vehicles in actual demand = (total period backup delay) + (total period speed delay).
- **average backup delay (min)** = average backup delay of all vehicles in actual demand.
- **average speed delay (min)** = average speed delay of all vehicles in actual demand.
- **average delay (min)** = average delay of all vehicles in actual demand = (average backup delay) + (average speed delay).
- **user cost / design demand ($/V)** = average user cost for all vehicles that would normally arrive during the period = (period user cost) / (period design demand).
- **delay cost / actual demand ($/V)** = average delay cost for vehicles in actual demand = (delay cost) / (actual demand).
- **canceled cars (V)** = number of cars in design demand that do not make a trip due to construction.
- **canceled trucks (V)** = number of trucks in design demand that do not make a trip due to construction.
- **diverted cars (V)** = number of cars in design demand that divert around the work zone (or detour) due to construction.
- **diverted trucks (V)** = number of trucks in design demand that divert around the work zone (or detour) due to construction.
- **decrease to cars (V/period)** = number of cars in design demand that do not make a trip or that divert around the work zone (or detour) due to construction = (canceled cars) + (diverted cars).
- **decrease to trucks (V/period)** = number of trucks in design demand that do not make a trip or that divert around the work zone (or detour) due to construction = (canceled trucks) + (diverted trucks).
- **total period decrease** = number of cars and trucks in design demand that do not make a trip or that divert around the work zone (or detour) due to construction = (decrease to cars) + (decrease to trucks).
- **decrease cost cars ($)**= total user cost due to canceled cars and diverted cars.
- **decrease cost trucks ($)** = total user cost due to canceled trucks and diverted trucks.
- **delay cost cars ($)**= total user cost due to backup delay and speed delay of cars.
- **delay cost trucks ($)** = total user cost due to backup delay and speed delay of trucks.
- **decrease cost ($)** = total user cost due to canceled cars, canceled trucks, diverted cars, and diverted trucks = (decrease cost cars) + (decrease cost trucks).
- **delay cost ($)** = total user cost due to backup delay and speed delay = (delay cost cars) + (delay cost trucks).

- **user cost ($)** = total user cost due to construction = (decrease cost) + (delay cost).
- **TOT** = total for all 24 periods.
- **MAX** = maximum value of all 24 periods.
- **MIN** = minimum value of all 24 periods.
- **AVG** = average value for all vehicles. This is not the average of the values for the 24 periods, because each period has a different demand.

1.5.3.3.3 Summary Output

The summary output is the same as in the Summary View for the traffic maintenance direction and method used in the most recent computer run. The variables in summary output are described in Sec. 1.5.3.2.8 – Summary Output.

1.5.3.4 Traffic, User Cost, and Combined Views

1.5.3.4.1 General

As described in Sec. 1.5.3.1, Traffic View, User Cost View, and Combined View show a subset of period output for traffic variables, user cost variables, and a more reduced subset of both traffic and user cost variables, that are internally copied from the Overall View. They also each show all the input values and Summary Output that are also shown in the Summary View and Overall View. Each of these three views provides a concentrated focus on a more limited group of variables than the Overall View. These views are practical for transparencies for presentations or otherwise focusing attention on a selected subset of important results.

These views together provide no more information that is not contained in the Overall View, but in three times as many pages, which requires three times as much printing. It is also generally easier to understand detailed output when it is all together, as in the Overall View. Therefore, we generally only print, review, and keep the Overall Views, together with the Summary View. We only print the Traffic, User Cost, and Combined Views when there is a specific reason to do so.

1.5.3.4.2 Traffic View

The Traffic View, shown in Fig. 1-11, reports period output for variables related to traffic but not for variables related to user cost, for the most recent computer run. Like the Overall View, it provides a complete report of input values and the overall summary for one traffic maintenance direction and method. It also contains the following subset of period input and output variables that is also in the Overall View and described in Sec. 1.5.3.3.2 - Period Output:

- capacity
- historical demand
- design demand
- actual demand
- decrease to cars
- decrease to trucks
- end of period backup
- end of period backup length
- maximum delay
- average backup delay

Overall View

period length (min)	60	
annual traffic growth (%)	5.00%	
years of growth	2	
VEHICLE INPUT	cars	trucks
design demand (%)	90.0%	10.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION	
PROJECT	US 00 Overlay
TITLE	Example Problem
C.S.	90000
JOB #	00000
START DATE	6/00/98

REPORT INFORMATION	
REPORT	DETAILED USER COST REPORT
TITLE	OVERALL VIEW
DIVISION	
REPORT BY	R. I. Carr
REPORT DATE	1/2/97

NOTES:

METHOD INPUT		METHOD 1	
method title		7A-5P	
DISTANCE AND SPEED	(mi) (mph)	distance	speed
work zone	method travel	2.0	see delay
	normal travel	2.0	65.0
diversion	method travel	12.0	50.0
	normal travel	10.0	65
SPEED DELAY		threshold	range
capacity for speed delay (V/period)		1400	
speed (when D~0) (mph)		45	
speed (when D=C) (mph)		10	
DECREASE TO DEMAND		threshold	range
capacity for decreases to design demand (V/period)		1400	
canceled cars (with no delay) (%)		5.0%	
canceled trucks (with no delay) (%)			
canceled cars (with delay) (%/min)		1.0%	
canceled trucks (with delay) (%/min)			
diverted cars (with no delay) (%)		5.0%	
diverted trucks (with no delay) (%)			
diverted cars (with delay) (%/min)		1.0%	
diverted trucks (with delay) (%/min)		0.5%	
OTHER USER COST INPUT		cars	trucks
other user cost per vehicle ($/V)		$0.00	$0.00
user cost per diversion ($/V)		$1.53	$2.93

SUMMARY OUTPUT	
traffic method	7A-5P
direction	SE
total user cost	$35,433
user cost of delays	$27,903
user cost of decreases	$7,530
maximum backup (V)	347
maximum backup length (lane mi)	2.0
maximum delay (min.)	23.5
average delay (min)	5.9
total delay, except diversions (V hr)	2,586
total vehicles canceled(V)	2,850
total vehicles diverted (V)	2,960
total decrease in demand (V)	5,809
% decrease in demand	18.1%
delay per diverted vehicle (min)	5.2
total diversion delay (V hr)	255
average delay, including diversions (min)	5.8
total delay, including diversions (V hr)	2,841
user cost / design demand	$1.11
delay cost / actual demand	$1.06

Overall Go To: Summary Overall Traffic User Cost Combined Print: This View Summary Overall All Setup

direction: SE backup at start (V): 0

period (hr)	capacity (V/period)	hist. demand (V/period)	design demand (V/period)	actual demand (V/period)	backup eop (V)	backup length eop (lane.mile)	maximum delay (min)	total period delay (Vhr)	average backup delay (min)	average speed delay (min)	average delay (min)		user cost / design demand ($/V)	delay cost / actual demand ($/V)
12 A	3400	436	481	481	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
1 A	3400	252	278	278	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
2 A	3400	195	215	215	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
3 A	3400	76	84	84	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
4 A	3400	81	89	89	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
5 A	3400	133	147	147	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
6 A	3400	431	475	475	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
7 A	1400	1280	1411	1110	0	0.00	6.68	124	0.00	6.68	6.68		$1.22	$1.20
8 A	1400	1681	1853	1356	0	0.00	9.63	218	0.00	9.63	9.63		$1.61	$1.73
9 A	1400	1401	1545	1190	0	0.00	7.56	150	0.00	7.56	7.56		$1.34	$1.36
10 A	1400	1473	1624	1235	0	0.00	8.08	166	0.00	8.08	8.08		$1.42	$1.45
11 A	1400	1697	1871	1366	0	0.00	9.74	222	0.00	9.74	9.74		$1.63	$1.75
12 P	1400	1835	2023	1436	36	0.20	11.51	259	0.68	10.15	10.83		$1.76	$1.95
1 P	1400	1735	1913	1362	0	0.00	11.68	243	0.64	10.07	10.71		$1.74	$1.93
2 P	1400	1810	1996	1424	24	0.14	11.07	252	0.46	10.15	10.61		$1.73	$1.91
3 P	1400	2211	2438	1563	187	1.06	17.89	379	4.38	10.15	14.54		$2.14	$2.61
4 P	1400	2482	2736	1560	347	1.97	23.53	478	10.49	7.89	18.38		$2.44	$3.30
5 P	3400	2606	2873	2873	0	0.00	6.12	96	2.01	0.00	2.01		$0.36	$0.36
6 P	3400	1965	2166	2166	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
7 P	3400	1422	1568	1568	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
8 P	3400	1238	1365	1365	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
9 P	3400	1162	1281	1281	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
10 P	3400	825	910	910	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
11 P	3400	607	669	669	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
TOT	61,600	29,034	32,010	26,201				2,586				AVG	$1.11	$1.06
MAX	3400	2606	2873	2873	347	1.97	23.53	478	10.49	10.15	18.38	MAX	$2.44	$3.30
MIN	1400	76	84	84	0	0.00	0.00	0	0	0.00	0.00	MIN	$0.00	$0.00

Overall Go To: Summary Overall Traffic User Cost Combined Print: This View Summary Overall All Setup

period (hr)	canceled cars (V)	canceled trucks (V)	diverted cars (V)	diverted trucks (V)	decrease to cars (V/period)	decrease to trucks (V/period)	total period decrease (V/period)	decrease cost cars ($)	decrease cost trucks ($)	delay cost cars ($)	delay cost trucks ($)	decrease cost ($)	delay cost ($)	user cost ($)
12 A	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
1 A	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
2 A	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
3 A	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
4 A	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
5 A	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
6 A	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
7 A	148	0	148	5	297	5	301	$375	$14	$1,170	$164	$389	$1,334	$1,723
8 A	244	0	244	9	488	9	497	$617	$26	$2,043	$305	$643	$2,348	$2,992
9 A	175	0	175	6	349	6	355	$442	$17	$1,415	$202	$459	$1,617	$2,076
10 A	191	0	191	7	382	7	389	$484	$19	$1,569	$227	$503	$1,795	$2,298
11 A	248	0	248	9	496	9	505	$628	$27	$2,079	$312	$654	$2,391	$3,045
12 P	288	0	288	11	577	11	588	$729	$32	$2,424	$373	$761	$2,797	$3,558
1 P	270	0	270	10	541	10	551	$684	$30	$2,274	$349	$714	$2,623	$3,337
2 P	280	0	280	11	561	11	571	$709	$31	$2,357	$361	$740	$2,718	$3,458
3 P	429	0	429	18	857	18	875	$1,084	$52	$3,494	$591	$1,136	$4,085	$5,221
4 P	576	0	576	25	1,151	25	1,176	$1,456	$74	$4,334	$821	$1,530	$5,155	$6,685
5 P	0	0	0	0	0	0	0	$0	$0	$936	$104	$0	$1,040	$1,040
6 P	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
7 P	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
8 P	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
9 P	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
10 P	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
11 P	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
TOT	2,850	0	2,850	110	5,699	110	5,809	$7,209	$322	$24,095	$3,808	$7,530	$27,903	$35,433
MAX	576	0	576	25	1,151	25	1,176	$1,456	$74	$4,334	$821	$1,530	$5,155	$6,685
MIN	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0

Fig. 1-10 Overall View

- average speed delay
- average delay

1.5.3.4.3 User Cost View

The User Cost View, shown in Fig. 1-12, reports period output for variables related to user cost, for the most recent computer run. Like the Overall View, it provides a complete report of input values and the overall summary for one traffic maintenance direction and method. It also contains the following subset of period input and output variables that is also in the Overall View and described in Sec. 1.5.3.3.2 - Period Output:

- capacity
- actual demand
- cancel costs
- divert costs
- decrease cost cars
- decrease cost trucks
- delay cost cars
- delay cost trucks
- decrease cost
- delay cost
- user cost
- user cost / total vehicles

1.5.3.4.4 Combined View

The Combined View (also called Combo View), shown in Fig. 1-13, reports period output for a selected set of variables related to traffic and user cost, for the most recent computer run. Like the Overall View, it provides a complete report of input values and the overall summary for one traffic maintenance direction and method. It also contains the following subset of period input and output variables that is also in the Overall View and described in Sec. 1.5.3.3.2 - Period Output:

- capacity
- actual demand
- total decrease
- total delay
- end of period backup
- maximum delay
- average backup delay
- average speed delay
- decrease cost
- delay cost
- user cost
- delay cost / actual demand

Traffic View

period length (min)	60	
annual traffic growth (%)	0	
years of growth	2	
VEHICLE INPUT	**cars**	**trucks**
design demand (%)	90.0%	10.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION	
PROJECT TITLE	US 00 Overlay Example Problem
C.S.	90000
JOB #	00000
START DATE	6/00/98

REPORT INFORMATION	
REPORT TITLE	DETAILED USER COST REPORT TRAFFIC VIEW
DIVISION	
REPORT BY	R. I. Carr
REPORT DATE	1/2/97

NOTES:

METHOD INPUT		METHOD 1	
method title		7A-5P	
DISTANCE AND SPEED	(mi) (mph)	distance	speed
work zone	method travel	2	see delay
	normal travel	2	65
diversion	method travel	12	50
	normal travel	10	65
SPEED DELAY		threshold	range
capacity for speed delay (V/period)		1400	
speed (when D~0) (mph)		45	
speed (when D=C) (mph)		10	
DECREASE TO DEMAND		threshold	range
capacity for decreases to design demand (V/period)		1400	
canceled cars (with no delay) (%)		5.0%	
canceled trucks (with no delay) (%)			
canceled cars (with delay) (%/min)		1.0%	
canceled trucks (with delay) (%/min)			
diverted cars (with no delay) (%)		5.0%	
diverted trucks (with no delay) (%)			
diverted cars (with delay) (%/min)		1.0%	
diverted trucks (with delay) (%/min)		0.5%	
OTHER USER COST INPUT		cars	trucks
other user cost per vehicle ($/V)		$0.00	$0.00
user cost per diversion ($/V)		$1.53	$2.93

SUMMARY OUTPUT	
traffic method	7A-5P
direction	SE
total user cost	$35,433
user cost of delays	$27,903
user cost of decreases	$7,530
maximum backup (V)	347
maximum backup length (lane mi)	2.0
maximum delay (min.)	23.5
average delay (min)	5.9
total delay, except diversions (V hr)	2,586
total vehicles canceled(V)	2,850
total vehicles diverted (V)	2,960
total decrease in demand (V)	5,809
% decrease in demand	18.1%
delay per diverted vehicle (min)	5.2
total diversion delay (V hr)	255
average delay, including diversions (min)	5.8
total delay, including diversions (V hr)	2,841
user cost / design demand	$1.11
delay cost / actual demand	$1.06

Traffic | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

Direction: SE | backup at start (V) 0

period (hr)	capacity (V/period)	hist. demand (V/period)	design demand (V/period)	actual demand (V/period)	decrease to cars (V/period)	decrease to trucks (V/period)	backup eop (V)	backup length eop (lane.mile)	maximum delay (min)	average backup delay (min)	average speed delay (min)	average delay (min)
12 A	3400	436	481	481	0	0	0	0.00				0.00
1 A	3400	252	278	278	0	0	0	0.00	0.00	0.00	0.00	0.00
2 A	3400	195	215	215	0	0	0	0.00	0.00	0.00	0.00	0.00
3 A	3400	76	84	84	0	0	0	0.00	0.00	0.00	0.00	0.00
4 A	3400	81	89	89	0	0	0	0.00	0.00	0.00	0.00	0.00
5 A	3400	133	147	147	0	0	0	0.00	0.00	0.00	0.00	0.00
6 A	3400	431	475	475	0	0	0	0.00	0.00	0.00	0.00	0.00
7 A	1400	1280	1411	1110	297	5	0	0.00	6.68	0.00	6.68	6.68
8 A	1400	1681	1853	1356	488	9	0	0.00	9.63	0.00	9.63	9.63
9 A	1400	1401	1545	1190	349	6	0	0.00	7.56	0.00	7.56	7.56
10 A	1400	1473	1624	1235	382	7	0	0.00	8.08	0.00	8.08	8.08
11 A	1400	1697	1871	1366	496	9	0	0.00	9.74	0.00	9.74	9.74
12 P	1400	1835	2023	1436	577	11	36	0.20	11.51	0.68	10.15	10.83
1 P	1400	1735	1913	1362	541	10	0	0.00	11.68	0.64	10.07	10.71
2 P	1400	1810	1996	1424	561	11	24	0.14	11.07	0.46	10.15	10.61
3 P	1400	2211	2438	1563	857	18	187	1.06	17.89	4.38	10.15	14.54
4 P	1400	2482	2736	1560	1,151	25	347	1.97	23.53	10.49	7.89	18.38
5 P	3400	2606	2873	2873	0	0	0	0.00	6.12	2.01	0.00	2.01
6 P	3400	1965	2166	2166	0	0	0	0.00	0.00	0.00	0.00	0.00
7 P	3400	1422	1568	1568	0	0	0	0.00	0.00	0.00	0.00	0.00
8 P	3400	1238	1365	1365	0	0	0	0.00	0.00	0.00	0.00	0.00
9 P	3400	1162	1281	1281	0	0	0	0.00	0.00	0.00	0.00	0.00
10 P	3400	825	910	910	0	0	0	0.00	0.00	0.00	0.00	0.00
11 P	3400	607	669	669	0	0	0	0.00	0.00	0.00	0.00	0.00
TOT	61,600	29,034	32,010	26,201	5,699	110						
MAX	3400	2606	2873	2,873	1,151	25	347	1.97	23.53	10.49	10.15	18.38
MIN	1400	76	84	84	0	0	0	0.00	0.00	0.00	0.00	0.00

Fig. 1-11 Traffic View

User Cost View

period length (min)	60	
annual traffic growth (%)	0	
years of growth	2	
VEHICLE INPUT	cars	trucks
design demand (%)	90.0%	10.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION	
PROJECT TITLE	US 00 Overlay Example Problem
C.S.	90000
JOB #	00000
START DATE	6/00/98

REPORT INFORMATION	
REPORT TITLE	DETAILED USER COST REPORT TRAFFIC SHEET
DIVISION	
REPORT BY	R. I. Carr
REPORT DATE	1/2/97

NOTES:

METHOD INPUT		METHOD 1	
	method title	7A-5P	
DISTANCE AND SPEED	(mi) (mph)	distance	speed
work zone	method travel	2	see delay
	normal travel	2	65
diversion	method travel	12	50
	normal travel	10	65
SPEED DELAY		threshold	range
capacity for speed delay (V/period)		1400	
speed (when D~0) (mph)		45	
speed (when D=C) (mph)		10	
DECREASE TO DEMAND		threshold	range
capacity for decreases to design demand (V/period)		1400	
canceled cars (with no delay) (%)		5.0%	
canceled trucks (with no delay) (%)			
canceled cars (with delay) (%/min)		1.0%	
canceled trucks (with delay) (%/min)			
diverted cars (with no delay) (%)		5.0%	
diverted trucks (with no delay) (%)			
diverted cars (with delay) (%/min)		1.0%	
diverted trucks (with delay) (%/min)		0.5%	
OTHER USER COST INPUT		cars	trucks
other user cost per vehicle ($/V)		$0.00	$0.00
user cost per diversion ($/V)		$1.53	$2.93

SUMMARY OUTPUT	
traffic method	7A-5P
direction	SE
total user cost	$35,433
user cost of delays	$27,903
user cost of decreases	$7,530
maximum backup (V)	347
maximum backup length (lane mi)	2.0
maximum delay (min.)	23.5
average delay (min)	5.9
total delay, except diversions (V hr)	2,586
total vehicles canceled(V)	2,850
total vehicles diverted (V)	2,960
total decrease in demand (V)	5,809
% decrease in demand	18.1%
delay per diverted vehicle (min)	5.2
total diversion delay (V hr)	255
average delay, including diversions (min)	5.8
total delay, including diversions (V hr)	2,841
user cost / design demand	$1.11
delay cost / actual demand	$1.06

User Cost | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

Direction: SE | backup at start (V) 0

period (hr)	capacity (V/period)	actual demand (V/period)	cancel costs ($)	divert costs ($)	decrease cost cars ($)	decrease cost trucks ($)	delay cost cars ($)	delay cost trucks ($)	decrease cost ($)	delay cost ($)	user cost ($)	user cost / total vehicles ($/V)
12 A	3400	481	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
1 A	3400	278	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
2 A	3400	215	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
3 A	3400	84	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
4 A	3400	89	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
5 A	3400	147	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
6 A	3400	475	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
7 A	1400	1,110	$148	$241	$375	$14	$1,170	$164	$389	$1,334	$1,723	$1.22
8 A	1400	1,356	$244	$399	$617	$26	$2,043	$305	$643	$2,348	$2,992	$1.61
9 A	1400	1,190	$175	$284	$442	$17	$1,415	$202	$459	$1,617	$2,076	$1.34
10 A	1400	1,235	$191	$312	$484	$19	$1,569	$227	$503	$1,795	$2,298	$1.42
11 A	1400	1,366	$248	$406	$628	$27	$2,079	$312	$654	$2,391	$3,045	$1.63
12 P	1400	1,436	$288	$473	$729	$32	$2,424	$373	$761	$2,797	$3,558	$1.76
1 P	1400	1,362	$270	$444	$684	$30	$2,274	$349	$714	$2,623	$3,337	$1.74
2 P	1400	1,424	$280	$460	$709	$31	$2,357	$361	$740	$2,718	$3,458	$1.73
3 P	1400	1,563	$429	$707	$1,084	$52	$3,494	$591	$1,136	$4,085	$5,221	$2.14
4 P	1400	1,560	$576	$954	$1,456	$74	$4,334	$821	$1,530	$5,155	$6,685	$2.44
5 P	3400	2,873	$0	$0	$0	$0	$936	$104	$0	$1,040	$1,040	$0.36
6 P	3400	2,166	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
7 P	3400	1,568	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
8 P	3400	1,365	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
9 P	3400	1,281	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
10 P	3400	910	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
11 P	3400	669	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00
TOT	61600	26,201	$2,850	$4,681	$7,209	$322	$24,095	$3,808	$7,530	$27,903	$35,433	$1.11
MAX	3400	2,873	$576	$954	$1,456	$74	$4,334	$821	$1,530	$5,155	$6,685	$2.44
MIN	1400	84	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0.00

Fig. 1-12 User Cost View

Combined View

period length (min)	60	
annual traffic growth (%)	0	
years of growth	2	
VEHICLE INPUT	cars	trucks
design demand (%)	90.0%	10.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION	
PROJECT TITLE	US 00 Overlay Example Problem
C.S.	90000
JOB #	00000
START DATE	6/00/98

REPORT INFORMATION	
REPORT TITLE	DETAILED USER COST REPORT COMBINED VIEW
DIVISION	
REPORT BY	R. I. Carr
REPORT DATE	1/2/97

NOTES:

METHOD INPUT		METHOD 1	
method title		7A-5P	
DISTANCE AND SPEED	(mi) (mph)	distance	speed
work zone	method travel	2	see delay
	normal travel	2	65
diversion	method travel	12	50
	normal travel	10	65
SPEED DELAY		threshold	range
capacity for speed delay (V/period)		1400	
speed (when D~0) (mph)		45	
speed (when D=C) (mph)		10	
DECREASE TO DEMAND		threshold	range
capacity for decreases to design demand (V/period)		1400	
canceled cars (with no delay) (%)		5.0%	
canceled trucks (with no delay) (%)			
canceled cars (with delay) (%/min)		1.0%	
canceled trucks (with delay) (%/min)			
diverted cars (with no delay) (%)		5.0%	
diverted trucks (with no delay) (%)			
diverted cars (with delay) (%/min)		1.0%	
diverted trucks (with delay) (%/min)		0.5%	
OTHER USER COST INPUT		cars	trucks
other user cost per vehicle ($/V)		$0.00	$0.00
user cost per diversion ($/V)		$1.53	$2.93

SUMMARY OUTPUT	
traffic method	7A-5P
direction	SE
total user cost	$35,433
user cost of delays	$27,903
user cost of decreases	$7,530
maximum backup (V)	347
maximum backup length (lane mi)	2.0
maximum delay (min.)	23.5
average delay (min)	5.9
total delay, except diversions (V hr)	2,586
total vehicles canceled(V)	2,850
total vehicles diverted (V)	2,960
total decrease in demand (V)	5,809
% decrease in demand	18.1%
delay per diverted vehicle (min)	5.2
total diversion delay (V hr)	255
average delay, including diversions (min)	5.8
total delay, including diversions (V hr)	2,841
user cost / design demand	$1.11
delay cost / actual demand	$1.06

Combo | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

Direction: SE | backup at start (V) 0

period (hr)	capacity (V/period)	actual demand (V/period)	total decrease (V/period)	total delay (V/period)	backup eop (V)	maximum delay (min)	average backup delay (min)	average speed delay (min)	decrease cost ($)	delay cost ($)	user cost ($)	delay cost / actual demand ($/V)
12 A	3400	481	0	0	0	0.00	0.0	0.0	$0	$0	$0	$0.00
1 A	3400	278	0	0	0	0.00	0.0	0.0	$0	$0	$0	$0.00
2 A	3400	215	0	0	0	0.00	0.0	0.0	$0	$0	$0	$0.00
3 A	3400	84	0	0	0	0.00	0.0	0.0	$0	$0	$0	$0.00
4 A	3400	89	0	0	0	0.00	0.0	0.0	$0	$0	$0	$0.00
5 A	3400	147	0	0	0	0.00	0.0	0.0	$0	$0	$0	$0.00
6 A	3400	475	0	0	0	0.00	0.0	0.0	$0	$0	$0	$0.00
7 A	1400	1,110	301	124	0	6.68	0.0	6.7	$389	$1,334	$1,723	$1.20
8 A	1400	1,356	497	218	0	9.63	0.0	9.6	$643	$2,348	$2,992	$1.73
9 A	1400	1,190	355	150	0	7.56	0.0	7.6	$459	$1,617	$2,076	$1.36
10 A	1400	1,235	389	166	0	8.08	0.0	8.1	$503	$1,795	$2,298	$1.45
11 A	1400	1,366	505	222	0	9.74	0.0	9.7	$654	$2,391	$3,045	$1.75
12 P	1400	1,436	588	259	36	11.51	0.7	10.2	$761	$2,797	$3,558	$1.95
1 P	1400	1,362	551	243	0	11.68	0.6	10.1	$714	$2,623	$3,337	$1.93
2 P	1400	1,424	571	252	24	11.07	0.5	10.2	$740	$2,718	$3,458	$1.91
3 P	1400	1,563	875	379	187	17.89	4.4	10.2	$1,136	$4,085	$5,221	$2.61
4 P	1400	1,560	1,176	478	347	23.53	10.5	7.9	$1,530	$5,155	$6,685	$3.30
5 P	3400	2,873	0	96	0	6.12	2.0	0.0	$0	$1,040	$1,040	$0.36
6 P	3400	2,166	0	0	0	0.00	0.0	0.0	$0	$0	$0	$0.00
7 P	3400	1,568	0	0	0	0.00	0.0	0.0	$0	$0	$0	$0.00
8 P	3400	1,365	0	0	0	0.00	0.0	0.0	$0	$0	$0	$0.00
9 P	3400	1,281	0	0	0	0.00	0.0	0.0	$0	$0	$0	$0.00
10 P	3400	910	0	0	0	0.00	0.0	0.0	$0	$0	$0	$0.00
11 P	3400	669	0	0	0	0.00	0.0	0.0	$0	$0	$0	$0.00
TOT	61600	26,201	5,809	2,586					$7,530	$27,903	$35,433	$1.06
MAX	3400	2,873	1,176	478	347	23.53	10	10.15	$1,530	$5,155	$6,685	$3.30
MIN	1400	84	0	0	0	0.00	0	0.00	$0	$0	$0	$0.00

Fig. 1-13 Combined (Combo) View

1.5.4 CONSTRUCTION COST SHEET (CONSTRUCTION TAB)

1.5.4.1 General

In the Construction Cost Sheet we estimate and document project cost for alternative ways of maintaining traffic and changes in construction they require. We can then enter construction project cost, along with user cost, in the Impact Sheet, to compare user cost and construction cost of each alternative, to help us select the best project alternative.

In the Construction Cost Sheet, we estimate the cost of each alternative based on the difference in its cost and the project cost of the Standard Case. The **Standard Case** is the typical method of construction, for which we generally estimate cost of construction, as a basis for making typical project decisions. Generally, this is the construction method we would use if we had no special concerns regarding user cost. Therefore, it usually provides us a well understood basis for estimating differences in construction cost for alternative methods.

Our estimates of portions of the total cost are generally quite rough, and we tend to round-off to the closest 10% or 5%. Labor is generally the most important, because (1) labor is a large portion of the cost and (2) it is generally the most sensitive cost. Equipment is generally the next most important, for its size and sensitivity. Material is a large cost, but it usually is not highly sensitive to changes in traffic maintenance alternatives.

We are particularly interested in determining the hours each day and number of days that traffic will be maintained under construction conditions, because this is the basis for determining user cost per day and total user cost. We call these “lane-closed hours per day” and “lane-closed days”, because the most common manner of maintaining traffic during construction and maintenance is to close the lane in which work is performed. More general terms are “traffic maintenance hours per day” and “traffic maintenance days”, but these are more cumbersome terms.

CO^3 uses a difference method of estimating as its basic approach to estimating construction cost for alternative construction methods. In this approach, we first estimate the contract cost and lane-closed days for the Standard Case, using conventional methods by which the Department generally does its cost and duration estimating. We then estimate values of variables in the Standard Case cost that will be affected by changes in the alternatives and pertinent values for those variables. Then we input corresponding values for each alternative. The Construction Cost Sheet then calculates the estimated lane-closed days and project cost for each alternative. We can Copy and Paste Value the output values from the Construction Cost Sheet to the Impact Sheet, which provides us a combined summary of traffic impact, user cost, and construction cost for each method of maintaining traffic.

Inputs to the Construction Cost Sheet are shown in color on the monitor and in light gray here. The general steps are the following:

1. Input values for the standard case.
2. Input values for alternative methods of maintaining traffic.
3. Calculate estimated construction costs for alternative methods.

Use of each section is explained below, accompanied by an unnumbered figure representing the section.

Important differences among alternatives are marked with an ellipse, , to indicate their importance. To place an ellipse in a worksheet cell, we do the following:

- Move the cursor to a cell that has an ellipse, place the cursor over the ellipse such that the cursor changes to crossed double-ended arrows ✣ (which indicates the cursor is marking the ellipse, not the cell itself), and click the mouse to select the ellipse.
- Copy the ellipse, like any other object, either with the toolbar icon, by pushing Ctrl-C on the keyboard, or R-click and Copy.
- Move to the cell in which we want the ellipse, click in the cell to select it, and Paste: either with toolbar icon, Ctrl-V on the keyboard, or R-click and Paste.
- To remove an ellipse, select it as in the first step, and delete, either with the toolbar icon, Delete on keyboard, or R-click and Cut. (Note: Sometimes copying an ellipse to a cell several times will stack multiple ellipses. Deleting one will still leave the others. To delete all of them, just repeat this step until no ellipse remains.)

1.5.4.2 *Project Input*

CONSTRUCTION COST SHEET Project:	US 00 Overlay (Example Problem)				
By:	R. I. Carr 10/18/96			important	
Other:					
CONSTRUCTION COST	Standard Case	Alternative 1	Alternative 2	Alternative 3	
Copy This Sheet General Input method	10 hr day shift	10 hr day shift, with publicity	8 hr day shift, with publicity	10 hr night shift	Std = 10 hr day. Add publicity, at some cost, but to reduce user cost. 8 hr day shift tries to avoid rush hours. Night avoids most traffic.
contract cost ($)	$500,000	NA	NA	NA	Est, normal way
lane closed days (day)	12	NA	NA	NA	Est: 4 lanes x 6 mi @ 2 mi per day = 12 days
lane closed days per work day.	1.00	1.00	1.00	1.00	default. W/ daily closure, no reason to work weekends, etc
lane closed hours per day (hr/day)	10	10	8	10	Lane is closed while work is done.
relative productivity	1	1	1	0.95	default, except night est = 0.95

We first input, at the top of the sheet, a description that allows us to identify the project and correlate it with the other CO^3 elements. This generally includes the project name and the lead person who is making this analysis.

Next, we estimate and enter General Input for the Standard Case, the normal way we would perform the work. The General Input variables are the following:

- **method** = identifier of construction method, which normally includes both a construction identifier and a traffic maintenance identifier. E.g., 10 hr day shift.
- **contract cost ($)** = contract cost for lane-closed work. Input is determined by conventional cost estimating procedures
- **lane-closed days (day)** = number of days a lane will be closed. We estimate it from past experience. For example: past experience has shown a lane is closed 10 hr/day for a certain type of work, and it takes about 1.5 days to do 1 mi of lane. For 2 miles of 4 lane highway, lane-closed days = (2 mi / lane) * (4 lanes) * (1.5 days/mi) = 12 days.
- **lane-closed days per work day** = ratio of number of lane-closed days to number of days in which work is performed. This accounts for any difference the days that traffic is maintained and the days work is performed. If lane(s) is closed only when work is being performed, lane-closed days per work day = 1. If lane(s) is closed 24 hr/day, 7 days/wk, and work is performed 4 day/wk, lane-closed days per work day = 7 / 4 = 1.75. Default = 1.
- **lane-closed hours per day (hr/day)** = number of hours a lane is closed each day that lane(s) is closed. Default = 10.

CONSTRUCTION COST SHEET	Project:	US 00 Overlay (Example Problem)			
	By:	R. I. Carr 10/18/96		important	
	Other:				
CONSTRUCTION COST	Standard Case	Alternative 1	Alternative 2	Alternative 3	
Copy This Sheet **General Input** **method**	10 hr day shift	10 hr day shift, with publicity	8 hr day shift, with publicity	10 hr night shift	Std = 10 hr day. Add publicity, at some cost, but to reduce user cost. 8 hr day shift tries to avoid rush hours. Night avoids most traffic.
contract cost ($)	$500,000	NA	NA	NA	Est, normal way
lane closed days (day)	12	NA	NA	NA	Est: 4 lanes x 6 mi @ 2 mi per day = 12 days
lane closed days per work day	1.00	1.00	1.00	1.00	default. W/ daily closure, no reason to work weekends, etc
lane closed hours per day (hr/day)	10	10	8	10	Lane is closed while work is done.
relative productivity	1	1	1	0.95	default, except night est = 0.95
Labor Cost					
labor cost %	30%	NA	NA	NA	Not labor intensive. Labor > equip. Material is large.
fixed mobilization (standard crew hr)	0.00	0.00	0.00	0.00	default. No labor cost for mobilization w/ lane open.
shifts per day	1.00	1.00	1.00	1.00	default
crews per shift	1.00	1.00	1.00	1.00	default
workers per crew (relative)	1.00	1.00	1.00	1.00	default
productive hours per shift	9.00	9.00	7.00	9.00	Est lane closure + lane opening = 1 hr per day
paid hours per shift	10.00	10.00	8.00	10.00	default = same as lane closed hr
% premium time	0%	0%	0%	0%	default
premium cost ($PT/$ST)	1.40	1.40	1.40	1.40	default
workers (relative)	1.0	1.0	1.0	1.0	
work days	12.0	12.0	15.4	12.6	
lane closed days (day)	12.0	12.0	15.4	12.6	
productive hours, total	108.0	108.0	108.0	113.7	
worker production hours, total (relative)	108.0	108.0	108.0	113.7	
paid hours, total (relative)	120.0	120.0	123.4	126.3	
cost per paid hour (relative)	1.00	1.00	1.00	1.00	
labor cost index	1.00	1.00	1.03	1.05	
labor cost ($)	$150,000	$150,000	$154,286	$157,895	
labor cost difference ($)	na	$0	$4,286	$7,895	
Equipment Cost- Relative Based					
equipment cost %	20%	NA	NA	NA	Equip significant, < labor or material.
relative number of items	1.0	1.0	1.0	1.0	default
equipment fixed cost/item, relative					
equipment fixed cost, relative ($)	$0	$0	$0	$0	
equipment cost/day/item, relative					
equipment cost ($) (day based)*	$0	$0	$0	$0	
equipment cost/hr/item, relative	1.0	1.0	1.0	1.0	default
equipment cost ($) (hr based)*	$100,000	$100,000	$100,000	$105,263	
equipment cost, relative ($)	$100,000	$100,000	$100,000	$105,263	
equipment cost difference, relative ($)	na	$0	$0	$5,263	
Equipment Cost - Total Based					
relative number of items				1.0	
equipment fixed cost/item, total					
equipment fixed cost, total ($)	$0	$0	$0	$0	
equipment cost/day/item, total				$500	Est lighting and other nighttime related small equipment items.
equipment cost, total ($) (day based)*	0	0	0	$6,316	
equipment cost/hr/item, total					
equipment cost,total ($) (hr based)*	0	0	0	0	
equipment cost,total ($)	$0	$0	$0	$6,316	
equipment cost difference, total ($)	na	$0	$0	$6,316	
Material Cost					
material cost ($)				$3,000	Est 2% x (material = 30%) x $500,000 = $3,000
materal cost difference ($)	na	$0	$0	$3,000	
Traffic Maintenance Cost					
traffic maintenance fixed cost ($)					
traffic maintenance daily cost ($/day)					
traffic maintenance hourly cost ($/hr)					
traffic maintenance total cost ($)	$0	$0	$0	$0	
traffic maintenance cost difference ($)	na	$0	$0	$0	
Other Contract Cost				nighttime	
other % cost (%)				2.00%	Misc 10% x (20% cost) for night
other fixed cost ($)					
other daily cost ($/day)					
other hourly cost ($/hr)					
other total cost ($)	$0	$0	$0	$10,449	
other total cost difference ($)	na	$0	$0	$10,449	
Agency Cost		publicity	publicity		
agency % cost (%)					
agency fixed cost ($)		$10,000	$10,000		Est: publicity cost has first cost plus daily cost
agency daily cost ($/day)		$500	$500		
agency hourly cost ($/hr)					
agency total cost ($)	$0	$16,000	$17,714	$0	
agency cost difference ($)	na	$16,000	$17,714	$0	
Total Construction Cost					
contract cost ($)	$500,000	$500,000	$504,286	$532,923	
contract cost difference ($)	na	$0	$4,286	$32,923	
project cost ($)	$500,000	$516,000	$522,000	$532,923	
project cost difference ($)	na	$16,000	$22,000	$32,923	
Summary method	10 hr day shift	10 hr day shift, with publicity	8 hr day shift, with publicity	10 hr night shift	
lane closed hours per day (hr/day)	10	10	8	10	
lane closed days (day)	12.0	12.0	15.4	12.6	
labor cost ($)	$150,000	$150,000	$154,286	$157,895	
project cost ($)	$500,000	$516,000	$522,000	$532,923	

*Generally do not use both hr based and day based equip cost.

You can copy these values into Impact Sheet.

Fig. 1-14 Construction Cost Sheet

- **relative productivity** = estimated ratio of productivity of a method to productivity using Standard Case. By definition, relative productivity using Standard Case = 1. Default = 1 when Standard Case and alternative are both daytime or nighttime. Default = 0.95 when Standard Case is daytime and alternative is nighttime.

Lane-closed days per work day, lane-closed hours per day, and relative productivity are estimated based on the users past experience. Relative productivity can differ significantly from one, if a method requires a significantly different number of hours per unit of output than the standard method. For example, if an alternative method used automated methods that reduced the time required per m^3 of roadway by half, relative productivity = 2.

1.5.4.3 Labor Cost

Labor Cost					
labor cost %	30%	NA	NA	NA	Not labor intensive. Labor > equip. Material is large.
fixed mobilization (standard crew hr)	0.00	0.00	0.00	0.00	default. No fixed mobilization while lane is closed.
shifts	1.00	1.00	1.00	1.00	default
crews per shift	1.00	1.00	1.00	1.00	default
workers per crew (relative)	1.00	1.00	1.00	1.00	default
productive hours per shift	9.00	9.00	7.00	9.00	Est lane closure + lane opening = 1 hr per day
paid hours per shift	10.00	10.00	8.00	10.00	default = same as lane closed hr
% premium time	0%	0%	0%	0%	default
premium cost ($PT/$ST)	1.40	1.40	1.40	1.40	default
workers (relative)	1.0	1.0	1.0	1.0	
work days	12.0	12.0	15.4	12.6	
lane closed days (day)	12.0	12.0	15.4	12.6	
productive hours, total	108.0	108.0	108.0	113.7	
worker production hours, total (relative)	108.0	108.0	108.0	113.7	
paid hours, total (relative)	120.0	120.0	123.4	126.3	
cost per paid hour (relative)	1.00	1.00	1.00	1.00	
labor cost index	1.00	1.00	1.03	1.05	
labor cost ($)	$150,000	$150,000	$154,286	$157,895	
labor cost difference ($)	na	$0	$4,286	$7,895	

Labor cost is generally the most sensitive to differences in construction methods, because the ways in which we most often change construction methods is to work a different number of hours per day or week, to work a different set of hours, to change the work tasks, or to change the number of workers or crews. All of these can significantly impact construction cost. Therefore, the most important elements in the Construction Cost Sheet relate to differences in labor cost.

We estimate the following variables, based on our experience:

- **labor cost %** = estimated fraction of contract cost that is labor cost related to work performed with lane(s) closed, including fixed mobilization.
- **fixed mobilization (standard crew hr)**= fixed number of standard crew hours or work required while lane is not closed, that are to be included in labor cost. Default = 0.
- **shifts per day** = number of work shifts per workday. Default = 1.
- **crews per shift** = number of work crews per shift
- **workers per crew (relative)**= relative number of workers per work crew. Default = 1.
- **productive hours per shift** = number of hours in which actual productive work performed during each shift. Generally, productive hours per shift = (lane-closed hours per day) – (daily mobilization and demobilization time while lane is closed).
- **paid hours per shift** = number of hours for which workers are paid each shift. Default = 10, for normal work week of four days of 10 hr/day.

- **% premium time** = percent of paid hours that is considered “overtime” for payroll purposes and for which “overtime” pay will be paid. Default = 0, for paid hours per shift = 10 and four shifts per week for each crew.
- **premium cost ($PT/$ST)** = ratio of premium time pay per hour ($PT) to standard time pay per hour ($ST). Default = 1.4.

Punch F9 on keyboard, and CO^3 calculates the following from the input above, for the Standard Case (standard) and alternative methods (alternative):

- **workers (relative)** = the relative number of workers per day, considering workers per crew, crews per shift, and number of shifts per day = (shifts per day) * (crews per shift) * (workers per crew).

- **work days** = number of days on which work is performed while lane is closed

$$= (\text{standard work days}) * \left(\frac{\text{standard relative productivity}}{\text{alternative relative productivity}}\right) * \left(\frac{\text{standard workers}}{\text{alternative workers}}\right) * \left(\frac{\text{standard productive hours per shift}}{\text{alternative productive hours per shift}}\right)$$

- **lane-closed days (day)** = number of days with lane(s) closed = number of days with traffic maintained under work conditions = (lane-closed days per work day) * (work days).

- **productive hours, total (hr)** = total number of hours in which actual productive work is performed = (shifts per day) * (productive hours per shift) * (work days)

- **worker production hours, total (relative)** = number of worker-hours of productive work that is performed =(work days) * (workers) * (productive hours per shift)
- **paid hours, total (relative)** = total number of hours for which workers are paid = (paid hours per shift) * (workers) * (work days) + (fixed mobilization)
- **cost per paid hour (relative)** = relative labor cost of each hour that is paid = (premium cost – 1) * (% premium time) + 1
- **labor cost index** = labor cost relative to the labor cost of the Standard Case,

$$= \left(\frac{\text{alternative paid hours, total}}{\text{standard paid hours, total}}\right) * \left(\frac{\text{alternative cost per paid hour}}{\text{standard cost per paid hour}}\right)$$

- **labor cost ($)** = labor cost for this construction method. Standard labor cost = (standard labor cost %) * (standard contract cost). Alternative labor cost = (alternative labor cost index) * (standard labor cost0

- **labor cost difference ($)** = difference between labor cost of alternative method and labor cost of standard case = (alternative labor cost) – (standard labor cost)

1.5.4.4 Equipment Cost

1.5.4.4.1 General

Equipment cost can differ significantly for different methods of construction, including different working hours, and we estimate these differences in the two equipment cost sections of the Construction Cost Sheet. If we do not estimate equipment cost will significantly differ for the construction methods we are estimating, we simply leave each variable in its default condition. For most variables, default = blank = 0.

The best individual approach to modeling equipment cost for lane closure work will depend on the equipment used, which depends on the nature of the work. For this reason, two basic equipment costing methods are included:

- **Relative based method**, which is the default method. This approach to equipment cost estimating parallels the approach used for labor cost.
- **Total based method**, where we can identify specific items of equipment and their costs

Similarly, equipment is rented or accounted for in three the following three ways, each of which is provided for in CO^3:

- **fixed cost** = fixed cost per project per piece of equipment
- **daily cost** = cost per day of use per piece of equipment
- **hourly cost** = cost per hour of use per piece of equipment, which is the default method.

1.5.4.4.2 Equipment Cost – Relative Based

Equipment Cost- Relative Based					
equipment cost %	20%	NA	NA	NA	Equip significant, < labor or material.
relative number of items	1.0	1.0	1.0	1.0	default
equipment fixed cost/item, relative					
equipment fixed cost, relative ($)	$0	$0	$0	$0	
equipment cost/day/item, relative					
equipment cost ($) (day based)*	$0	$0	$0	$0	
equipment cost/hr/item, relative	1.0	1.0	1.0	1.0	default
equipment cost ($) (hr based)*	$100,000	$100,000	$100,000	$105,263	
equipment cost, relative ($)	$100,000	$100,000	$100,000	$105,263	
equipment cost difference, relative ($)	na	$0	$0	$5,263	

The Equipment Cost – Relative Based section estimates alternative construction method equipment costs based on their ratio to standard method costs, in a manner similar to labor cost estimating. In parallel with earlier calculations of the Standard Case labor cost, **Standard Case equipment cost** = standard equipment cost = (standard contract cost) * (equipment cost %).

We first input equipment cost % for the Standard Case:

equipment cost % = percent of Standard Case contract cost that is estimated to be equipment cost. This is used in the relative based method of equipment costing. Default > 0. If equipment cost is not important or if only total based equipment costing is used, equipment cost % = 0 = blank.

We input the relative number of items for each method:

- **relative number of items** = relative number of pieces of equipment used by each construction method in its lane-closed work. Default = 1. If the mix of equipment differs with construction method, weight the relative number of items by relative cost. Differences occur for various reasons:
  - Example: If two crews are used, and each crew requires a set of equipment, relative number of items = 2.

- Example: Standard Case relative number of items = 1. Standard Case uses one paver (relative cost = 1) and three rollers (relative cost = 0.2 each). Alternative 1 uses one paver and 5 rollers. Therefore, alternative 1 relative number of items = 1 * [1+5*(0.2)] / [1+3*(0.2)] = 2 / 1.6 = 1.25.

We input values for each of the three types of equipment costing:

- **equipment fixed cost/item, relative** = relative cost per fixed cost equipment item used in lane-closed work. Default = 0 (blank).
  - standard fixed cost/item = fraction of Standard Case equipment cost that is fixed cost.
  - alternative fixed cost/item = fixed cost relative to standard fixed cost/item. Note: This is only relevant when standard fixed cost/item ≠ 0. If standard fixed cost/item = 0 and alternative fixed cost/item ≠ 0, we must enter its value in (equipment fixed cost/item, total) in the Equipment Cost - Total Based input section.
- **equipment cost/day/item, relative** = relative cost per day per equipment item used in lane-closed work. Default = 0 (blank).
  - standard cost/day/item = fraction of Standard Case equipment cost that is based on daily cost.
  - alternative cost/day/item = daily cost relative to standard cost/day/item. Note: This is only relevant when standard cost/day/item ≠ 0. If standard cost/day/item = 0 and alternative cost/day/item ≠ 0, we must enter its value in (equipment cost/day/item, total) in the Equipment Cost - Total Based input section.
- **equipment cost/hr/item, relative** = relative cost per hour per equipment item used in lane-closed work. Default = 1. For the Standard Case, this the fraction of equipment cost that is based on number of hours of use.
  - standard cost/hr/item = fraction of Standard Case equipment cost that is based on hourly cost.
  - alternative cost/hr/item = hourly cost relative to standard cost/hr/item. This is only relevant when standard cost/hr/item ≠ 0. If standard cost/hr/item = 0 and alternative cost/hr/item ≠ 0, we must enter its value in (equipment cost/hr/item, total) in the Equipment Cost - Total Based input section.

For the Standard Case, we require that (standard fixed cost/item) + (standard cost/day/item) + (standard cost/hr/item) = 1.

The Construction Cost Sheet calculates

- **equipment fixed cost, relative ($)** = cost of equipment whose cost is fixed.
  - standard cost = (standard equipment cost) * (standard equipment fixed cost/item, relative).
  - alternative cost = (standard cost) * [(alternative relative number of items) / (standard relative number of items)] * [(alternative equipment fixed cost/item, relative) / (standard equipment fixed cost/item, relative)].
- **equipment cost ($) (day based)** = cost of equipment with cost based on days of use.
  - standard cost = (standard equipment cost) * (standard equipment cost/day/item, relative).

- alternative cost = (standard cost) * [(alternative relative number of items) / (standard relative number of items)] * [(alternative work days) / (standard work days)] * [(alternative equipment cost/day/item, relative) / (standard equipment cost/day/item, relative)].
- **equipment cost ($) (hr based)** = cost of equipment with cost based on hours of use.
  - standard cost = (standard equipment cost) * (standard equipment cost/hr/item, relative).
  - alternative cost = (standard cost) * [(alternative relative number of items) / (standard relative number of items)] * [(alternative productive hours) / (standard productive hours)] * [(alternative equipment cost/hr/item, relative) / (standard equipment cost/hr/item, relative)].
- **equipment cost, relative ($)** = (equipment fixed cost, relative) + [equipment cost (day based)] + [equipment cost (hour based)].
- **alternative equipment cost difference, relative ($)** = (alternative equipment cost, relative) – (standard equipment cost, relative).

1.5.4.4.3 Equipment Cost – Total Based

Equipment Cost - Total Based					
relative number of items				1.0	
equipment fixed cost/item, total					
equipment fixed cost, total ($)	$0	$0	$0	$0	
equipment cost/day/item, total				$500	Est lighting and other nighttime related small equipment items.
equipment cost, total ($) (day based)*	0	0	0	$6,316	
equipment cost/hr/item, total					
equipment cost,total ($) (hr based)*	0	0	0	0	
equipment cost,total ($)	$0	$0	$0	$6,316	
equipment cost difference, total ($)	na	$0	$0	$6,316	

The total cost approach calculates alternative method costs directly from Standard Case and alternative method equipment cost input. This approach does not use equipment cost %.

We input the relative number of items for each method:

- **relative number of items** = relative number of pieces of equipment used by each construction method in its lane-closed work. Default = 1. This is a direct multiplier for the cost per item below.

We input values for each of the three types of equipment costing:

- **equipment fixed cost/item, total** = total cost per equipment item of fixed cost equipment items used in lane-closed work. Default = 0 (blank).
- **equipment cost/day/item, total** = total cost per day per equipment item used in lane-closed work. Default = 0 (blank).
- **equipment cost/hr/item, total** = total cost per hour per equipment item used in lane-closed work. Default = 0 (blank)

The Construction Cost Sheet calculates

- **equipment fixed cost, relative ($)** = cost of equipment whose cost is fixed = (equipment fixed cost/item, total) * (relative number of items).
- **equipment cost ($) (day based)** = cost of equipment with cost based on days of use = (equipment cost/day/item, total) * (relative number of items) * (work days).
- **equipment cost ($) (hr based)** = cost of equipment with cost based on hours of use = (equipment cost/hr/item, total) * (relative number of items) * (productive hours).

- **equipment cost, total ($)** = (equipment fixed cost, total) + [equipment cost, total (day based)] + [equipment cost, total (hour based].
- **alternative equipment cost difference, relative ($)** = (alternative equipment cost, total) **–** (standard equipment cost, total).

1.5.4.4.4 Equipment Cost Sequence of Steps

The default sequence of estimating equipment cost is the following:

1. For relative based equipment cost, estimate equipment cost % and relative number of items (we usually use default=1) for the Standard Case.
2. Estimate the fractions of equipment cost that are fixed cost, daily cost, and hourly cost for the Standard Case.
3. If total based equipment cost is to be estimated, for Standard Case estimate relative number of items (default = 1) and magnitudes of total based equipment costs that are fixed costs, daily costs, and hourly costs.
4. For the relative based equipment cost for each alternative, estimate the relative number of items and the fixed cost, daily cost, and hourly cost per item, relative to the Standard Case.
5. For any total based equipment costs of each alternative, estimate relative number of items and magnitudes of fixed cost, daily cost, and hourly cost for each item.

1.5.4.4.5 Number of Items of Equipment

The number of items of equipment used in each construction method can be handled in either of two ways:

- relative number of items easily accommodates multiples, and it is the most commonly used.
  - Example: an alternative that uses two crews and therefore needs two sets of equipment relative to the Standard Case has alternative relative number of items = 2.
- alternative fixed cost/item, daily cost/item, and hourly cost/item can accommodate both differences in number of items and differences in cost per item.
  - Example: (standard equipment cost/day/item, relative) = 0.6, which indicates 0.6 of the equipment cost is daily cost. An alternative is expected to use half again as much daily cost equipment as the Standard Case, and the equipment is expected to cost 20% more per item. Therefore, (alternative equipment cost/day/item, relative) = (0.6) * (1 + 0.5) * (1 + 0.2) = 1.08.
  - Example: (standard equipment cost/hr/item, total) = $200/hr. An alternative is expected to use twice as many pieces of equipment, each costing 80% of the hourly cost in the Standard Case. Therefore, alternative equipment cost/hr/item, total = (200) * (2) * (0.8) = $320/hr.

1.5.4.5 Material, Traffic Maintenance, Other Contract, and Agency Costs

1.5.4.5.1 General

Material, traffic maintenance, and agency costs are usually major parts of project cost, but they usually do not differ significantly among the construction methods that we evaluate for user cost. Therefore, we generally do not include them in our CO[3] analysis, and the default value for each of these costs is zero (blank). There are exceptions, of course, such as using quicker setting materials so work goes faster or constructing a detour to decrease congestion. We include these sections in the Construction Cost Sheet, so we can consider them in our decisions. However, in each case, we only input the particular costs that will differ, because we only include the differences between Standard Case cost and alternative cost in our contract cost and project cost calculations.

For traffic maintenance cost, other contract cost, and agency cost we can input fixed cost, daily cost, and hourly cost. However, we only input costs where the alternative(s) differ from the Standard Case, due to difference in their fixed cost, daily cost, or hourly cost or due to difference in the number of days or hours of lane closure.

Material Cost					
material cost ($)				$3,000	Est 2% x (material = 30%) x $500,000 = $3,000
materal cost difference ($)	na	$0	$0	$3,000	
Traffic Maintenance Cost					
traffic maintenance fixed cost ($)					
traffic maintenance daily cost ($/day)					
traffic maintenance hourly cost ($/hr)					
traffic maintenance total cost ($)	$0	$0	$0	$0	
traffic maintenance cost difference ($)	na	$0	$0	$0	
Other Contract Cost				nighttime	
other % cost (%)				2.00%	Misc 10% x (20% cost) for night
other fixed cost ($)					
other daily cost ($/day)					
other hourly cost ($/hr)					
other total cost ($)	$0	$0	$0	$10,449	
other total cost difference ($)	na	$0	$0	$10,449	
Agency Cost		publicity	publicity		
agency % cost (%)					
agency fixed cost ($)		$10,000	$10,000		Est: publicity cost has first cost plus daily cost
agency daily cost ($/day)		$500	$500		
agency hourly cost ($/hr)					
agency total cost ($)	$0	$16,000	$17,714	$0	
agency cost difference ($)	na	$16,000	$17,714	$0	

1.5.4.5.2 Material Cost

- **material cost ($)** = estimated cost of materials included in the contract cost. We generally include only costs of materials that differ among alternatives. Default = 0 (blank).
- **material cost difference ($)** = difference between material cost of an alternative and material cost of the Standard Case = (alternative material cost) – (standard material cost).

1.5.4.5.3 Traffic Maintenance Cost

- **traffic maintenance fixed cost ($)** = cost of traffic maintenance that does not vary with number of days or hours of lane closure.
- **traffic maintenance daily cost ($/day)** = cost per day for traffic maintenance that is a function of the number of days of lane closure.
- **traffic maintenance hourly cost ($/hr)** = cost per hour for traffic maintenance that is a function of the number of hours of lane closure.
- **traffic maintenance total cost ($)** = total cost of maintaining traffic during construction = (traffic maintenance fixed cost) + [(traffic maintenance daily cost) + (traffic maintenance hourly cost) * (lane-closed hours per day)] * (lane-closed days).
- **traffic maintenance cost difference ($)** = (alternative traffic maintenance total cost) – (standard traffic maintenance total cost).

1.5.4.5.4 Other Contract Cost

Other contract cost consists of any other costs in the contract that are not accommodated in labor, equipment, material, or traffic maintenance cost. We try to identify them in the rightmost column. We can include other contract cost as a fraction of labor, equipment, material, and traffic maintenance cost; and we include it as fixed cost, daily cost, and hourly cost.

- **other % cost (%)** = other contract cost that is a percentage of labor, equipment, material, and traffic maintenance cost.
- **other fixed cost ($)** = other contract cost that does not vary with number of days or hours of work.
- **other daily cost ($/day)** = cost per day for other contract cost that is a function of the number of work days.
- **other hourly cost ($/hr)** = cost per hour for other contract cost that is a function of the number of paid hours.
- **other total cost ($)** = total other contract cost = (other % cost) * [(Standard Case contract cost) + (labor cost difference) + (equipment cost difference, relative) + (equipment cost difference, total) + (material cost difference) + (traffic maintenance cost difference)] + (other fixed cost) + (other daily cost) * (work days) + (other hourly cost) * [(paid hours, total (relative)].
- **other cost difference ($)** = (alternative other total cost) **–** (standard other total cost).

1.5.4.5.5 Agency Cost

Agency cost consists of costs the Department has that are not included in contract costs. This can include costs of Department personnel, purchase of engineering or inspection services, and Department furnished material.

- **agency % cost (%)** = agency cost that is a percentage of contract cost.
- **agency fixed cost ($)** = agency cost that does not vary with number of days or hours of work.
- **agency daily cost ($/day)** = cost per day for agency cost that is a function of the number of work days.
- **agency hourly cost ($/hr)** = cost per hour for agency cost that is a function of the number of paid hours.
- **agency total cost ($)** = total agency cost = (agency % cost) * (contract cost) + (agency fixed cost) + (agency daily cost) * (work days) + (agency hourly cost) * [(paid hours, total (relative)].
- **agency cost difference ($)** = (alternative agency total cost) **–** (standard agency total cost).

1.5.4.6 Total Construction Cost and Summary

Total Construction Cost					
contract cost ($)	$500,000	$500,000	$504,286	$532,923	
contract cost difference ($)	na	$0	$4,286	$32,923	
project cost ($)	$500,000	$516,000	$522,000	$532,923	
project cost difference ($)	na	$16,000	$22,000	$32,923	
Summary method	10 hr day shift	10 hr day shift, with publicity	8 hr day shift, with publicity	10 hr night shift	
lane closed hours per day (hr/day)	10	10	8	10	
lane closed days (day)	12.0	12.0	15.4	12.6	
labor cost ($)	$150,000	$150,000	$154,286	$157,895	
project cost ($)	$500,000	$516,000	$522,000	$532,923	

*Generally do not use both hr based and day based equip cost.

You can copy these values into Impact Sheet.

1.5.4.6.1 Total Construction Cost

This calculates and reports the overall results of the Construction Cost Sheet, which consists of the contract cost and project cost of each alternative and the magnitude of their differences from the Standard Case. Therefore, this is the "bottom line" of the impact of different methods of construction and traffic maintenance on construction cost.

- **contract cost ($)** = estimated total contract cost. For each alternative, contract cost = (Standard Case contract cost) + (labor cost difference) + (equipment cost difference, relative) + (equipment cost difference, total) + (material cost difference) + (traffic maintenance cost difference) + (other contract cost difference).
- **contract cost difference ($)** = difference between the contract cost of an alternative and the Standard Case contract cost = (alternative contract cost) – (Standard Case contract cost).
- **project cost ($)** = total cost of construction, including agency cost = (contract cost) + (agency cost).
- **project cost difference ($)** = difference between the project cost of an alternative and the Standard Case project cost = (alternative project cost) – (Standard Case project cost).

1.5.4.6.2 Summary

The Summary provides a short summary of the most important variables calculated on the Construction Cost Sheet, which have been described above. They are collected here so they can quickly be viewed together and they can be directly copied and value-pasted into the Impact Sheet. There, they are combined with user cost to show the combined impact of alternative construction and traffic maintenance methods on user cost and construction cost. The variables summarized are the following:

- **lane-closed hours per day (hr/day)** – see Sec. 1.5.4.2, pg. 1-43.
- **lane-closed days (day)** – see Sec. 1.5.4.3, pg. 1-45.
- **labor cost ($)** – see Sec. 1.5.4.3, pg. 1-45.
- **project cost ($)** – see Sec. 1.5.4.6.1, pg. 1-53.

1.5.5 IMPACT SHEET (IMPACT TAB)

1.5.5.1 General

The Impact Sheet, also called the Impact Summary Sheet, reports daily user cost, total user cost, construction cost, and total project cost including user cost for different methods of maintaining traffic. Its purpose is to show in one place a summary of traffic, user cost, and construction cost so we can understand the overall impact of each method of maintaining traffic. Fig. 1-15 shows an example of the Impact Sheet computer screen. The shaded upper portion is for input of values from the Output Summary of the Summary View of the Traffic Sheet and from the Summary portion of the Construction Sheet. This portion is not normally printed. As with other worksheets, the Impact Sheet contains control buttons and background instructions that are for our computer use but are not printed.

The lower portion is the part that is normally printed as a report, and much of its output is not reported anywhere else. Its values are calculated from input into the upper portion, using equations in the cells of the lower portion. We must not input data directly into the lower portion or delete values that it reports, because doing so will delete the equations in its cells.

1.5.5.2 Summary Input

Other than % closed values, input to the Impact Sheet, labeled Summary Input, comes from two sources:

- Summary Output from the bottom of the Summary View of the Traffic Sheet. (See Sec. 1.5.3.2.8, pg. 1-28)
- Summary from the bottom of the Construction Cost Sheet. See Sec. 1.5.4.6.2, pg. 1-53)

For each traffic maintenance and construction method, we can easily Copy and Paste Values from the Summary View and the Construction Cost Sheet directly into the Impact Sheet. These variables are explained at the points referenced above, and they are not explained here. The appropriate areas from which the inputs are copied and to which they are pasted are marked by text boxes in the Summary View of the Traffic Sheet, Construction Cost Sheet, and Summary Input of the Impact Sheet.

In the Impact Sheet, we must input % closed = fraction of time each direction is closed to distinguish between the two common types of lane closure: (1) a lane is closed in one direction each day and (2) a lane is closed in both directions each day. An example of the first is pavement overlay of a four lane road, in which one lane is closed for work each day. An example of the second is reconstructing a four lane divided road, in which both lanes on one side of the median are closed each day, while traffic is one lane in each direction on the other side of the median. The % closed determines whether the traffic impacts and user cost per day is the average of the impact and user cost of the two directions (because a lane is closed in one direction every day) or their sum (because a lane is closed in both directions every day):

- **% closed** = fraction of the days of lane closure on which the direction is closed.
  - % closed = 50% indicates the direction is closed half of the days of lane closure. I.e., a lane is closed in one direction each day but not the other.
  - % closed = 100% indicates the direction is closed all days of lane closure. I.e., a lane is closed in both directions each day.

- % closed may be a value other than 50% or 100%, for the less common case that the two directions are closed different numbers of days or when each is closed more than half the time but not all the time.
  - Example: The east-bound lane requires half again as much work as the west-bound lane. Therefore, east-bound % closed = 1.5 / (1.5 + 1) = 60%, and west-bound % closed = 1 / / (1.5 + 1) = 40%.
  - Example: Two of four lanes will be closed 60% of the time and one lane will be closed 40% of the time, 20% in each direction. Therefore, for each direction % closed = 60 + 20 = 80%.

IMPACT SUMMARY SHEET

SUMMARY SHEET INPUT	Project:	US 00 Overlay (Example Problem)
Copy This Sheet	By:	R. I. Carr 12/31/96
	Other:	

TRAFFIC SUMMARY INPUT % closed	50%	50%	50%	50%	50%	50%	50%	50%
traffic method	7A-5P		7A-5P, Publicity		7A-3P, Publicity		Night, 8P-6A	
direction	SE	NW	SE	NW	SE	NW	SE	NW
total user cost ($)	$35,433	$37,919	$25,250	$26,599	$17,712	$20,876	$4,818	$4,275
user cost of delays ($)	$27,903	$29,737	$14,828	$15,560	$10,680	$12,241	$4,183	$3,720
user cost of decreases ($)	$7,530	$8,183	$10,421	$11,039	$7,032	$8,635	$634	$556
maximum backup (V)	347	264	347	0	0	0	0	0
maximum backup length (lane mi)	2.0	1.5	2.0	0.0	0.0	0.0	0.0	0.0
maximum delay (min.)	23.5	21.5	23.5	9.2	7.5	9.2	7.4	6.4
average delay (min)	5.9	6.4	5.9	3.6	2.2	2.7	0.7	0.7
total delay, except diversions (V hr)	2586	2756	2586	1442	990	1134	388	345
total vehicles canceled (V)	2850	3094	2850	4221	2689	3302	236	207
total vehicles diverted (V)	2960	3216	2960	4221	2689	3302	249	218
total decrease in demand (V)	5809	6310	5809	8442	5378	6604	484	424
% decrease in demand	18.1%	19.6%	24.9%	26.2%	16.8%	20.5%	1.5%	1.3%
delay per diverted vehicle (min)	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
total diversion delay (V hr)	255	277	255	364	232	284	21	19
average delay, including diversions (min)	5.8	6.3	6.3	3.9	2.5	2.9	0.8	0.7
total delay, including diversions (V hr)	2841	3033	2841	1806	1221	1419	409	363
user cost / design demand ($/V)	$1.11	$1.18	$0.79	$0.83	$0.55	$0.65	$0.15	$0.13
delay cost / actual demand ($/V)	$1.06	$1.15	$0.62	$0.66	$0.40	$0.48	$0.13	$0.12

Paste Values — PASTE VALUE S only from Summary View of Traffic Sheet. Use DELETE to undo.

CONSTRUCTION SUMMARY INPUT	10 hr day shift		10 hr day shift, with publicity		8 hr day shift, with publicity		10 hr night shift	
lane-closed hours per day (hr/day)	10		10		8		10	
lane-closed days (day)	12.0		12.0		15.4		12.6	
labor cost ($)	$150,000		$150,000		$154,286		$157,895	
project cost ($)	$500,000		$516,000		$522,000		$532,923	

Paste Values — PASTE VALUES only from Construction Sheet. Use DELETE to undo.

Copy This Sheet

Print Summary of Impacts for 4 Methods, Vertical

SUMMARY OF IMPACTS	US 00 Overlay (Example Problem)			
By:	R. I. Carr 12/31/96			
Other:	Do not change or copy in summaries below this area			
USER COST, DAILY traffic method	**7A-5P**	**7A-5P, Publicity**	**7A-3P, Publicity**	**Night, 8P-6A**
total user cost, daily ($)	$36,676	$25,924	$19,294	$4,547
user cost of delays, daily ($)	$28,820	$15,194	$11,460	$3,952
user cost of decreases , daily ($)	$7,857	$10,730	$7,834	$595
total delay, except diversions, daily (V hr)	2,671	2,014	1,062	366
total vehicles canceled, daily (V)	2,972	3,535	2,995	221
total vehicles diverted, daily (V)	3,088	3,590	2,995	233
total decrease in demand, daily (V)	6,059	7,125	5,991	454
total diversion delay, daily (V hr)	266	309	258	20
total delay, including diversions, daily (V hr)	2,937	2,323	1,320	386
USER COST, TOTAL				
total user cost ($)	$440,114	$311,091	$297,681	$57,432
user cost of delays ($)	$345,836	$182,330	$176,819	$49,914
user cost of decreases ($)	$94,278	$128,761	$120,863	$7,518
maximum backup (V)	347	347	0	0
maximum backup length (lane mi)	2.0	2.0	0.0	0.0
maximum delay (min.)	23.5	23.5	9.2	7.4
average delay (min)	6.2	4.8	2.4	0.7
total delay, except diversions (V hr)	3,192	3,712	3,981	254
total vehicles canceled (V)	35,662	42,423	46,213	2,792
total vehicles diverted (V)	37,051	43,082	46,213	2,947
total decrease in demand (V)	72,713	85,505	92,427	5,740
% decrease in demand	18.9%	25.6%	18.7%	1.4%
average delay per diverted vehicle (min)	5.2	5.2	5.2	5.2
total diversion delay (V hr)	3,192	3,712	3,981	254
average delay, including diversions (min)	6.1	5.1	2.7	0.7
total delay, including diversions (V hr)	35,244	27,880	20,369	4,880
average user cost / design demand ($/V)	$1.14	$0.81	$0.60	$0.14
average delay cost / actual demand ($/V)	$1.11	$0.64	$0.44	$0.12
CONSTRUCTION COST method	10 hr day shift	10 hr day shift, with publicity	8 hr day shift, with publicity	10 hr night shift
lane-closed hours per day (hr/day)	10	10	8	10
lane-closed days (day)	12.0	12.0	15.4	12.6
labor cost ($)	$150,000	$150,000	$154,286	$157,895
project cost ($)	$500,000	$516,000	$522,000	$532,923
TOTAL PROJECT COST	**$940,114**	**$827,091**	**$819,681**	**$590,355**

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Do not change these areas or copy into these areas.

Fig. 1-15 Impact Sheet (including Summary Sheet Input)

1.5.5.3 Summary of Impacts

The user cost values in the Summary of Impacts are calculated from the Summary Sheet Input. Each variable has already been described in Summary Output of the Summary View of the Traffic Sheet, Sec. 1.5.3.2.8, pg. 1-28, for a one day of lane closure in one direction. The values in this Summary of Impacts are different in two ways: (1) In the User Cost, Daily section, we see the average or total impact for each day of lane closure. (2) In the User Cost, Total section, we see the total impact for the duration of the project. And at the very bottom we see the total project cost = (total user cost for the project) + (project cost from the Construction Cost Sheet). We therefore have, in one report, the daily and total traffic impacts, user cost, and construction cost values for each traffic maintenance and construction method. We can easily compare them to help us select from among them.

We can easily print the report using either of two control buttons:

- **Print Summary of Impacts for 4 Methods, Vertical –** prints the variable titles and Summary of Impacts for the leftmost four methods down the length of the page, in normal “Portrait” page orientation.
- **Print Summary of Impacts for 7 Methods, Horizontal –** prints the variable titles and Summary of Impacts for all seven methods across the length of the page, in “Landscape” page orientation.

Below the Summary of Impacts, there is room for us to type 12 lines of comments, which will be printed with the Summary of Impacts as part of the report.

The **User Cost, Daily** variables provide the average impact for each day of lane closure. The general formula for each variable, *x*, for directions *a* and *b*, is

$$(\text{daily value of } x) = (\%\text{ closed})_a * x_a + (\%\text{ closed})_b * x_b \tag{20}$$

For example, in Fig. 1-15, for 7A-5P, (total user cost, daily) = (SE % lane-closed) * (SE total user cost) + (NW % lane-closed) * (NW total user cost) = (50%) * (35,433) + (50%) * (37,919) = $36,676.

User Cost, Total variables provide output for the traffic impact and user cost for the duration of the project. Some of the output variables report the total for all days of project lane closure:

- total user cost ($)
- user cost of delays ($)
- user cost of decreases ($)
- total delay, except diversions (V hr)
- total vehicles canceled (V)
- total vehicles diverted (V)
- total decrease in demand (V)
- total diversion delay (V hr)
- total delay, including diversions (V hr)

The formula for the total of each variable, *x*, is

$$(\text{total value of } x) = (\text{daily value of } x) * (\text{lane - closed days}) \tag{21}$$

For example, for 7A-5P, (total user cost) = (total user cost, daily) * (lane-closed days) = (36,676) * (12.0) = $440,114.

Some of the output values are the maximum value for either direction:

- maximum backup (V)
- maximum backup length (lane mi)

Some variables provide the average value for the two directions:

- average delay (min) (for vehicles in actual demand)
- average delay per diverted vehicle (min). (This delay is usually the same for all vehicles in both directions.)
- average delay, including diversions (min)
- average user cost / design demand ($/V)
- average delay cost / actual demand ($/V)

The formula for the average of each variable, *x*, for directions *a* and *b*, is

$$(\text{average value for } x) = \frac{(\%\text{ closed})_a * x_a + (\%\text{ closed})_b * x_b}{(\%\text{ closed})_a + (\%\text{ closed})_b} \qquad (22)$$

For example, for 7A-5P, (average delay) = [(SE % lane-closed) * (SE average delay) + (NW % lane-closed) * (NW average delay)] / [(SE % lane-closed) + (NW % lane-closed)] = [(50%) * (5.9) + (50%) * (6.4)] / (50% + 50%) = 6.2.

The bottom line of the analysis is described by total project cost = (total user cost) + (project cost). For example, for 7A-5P, total project cost = (440,114) + (500,000) = $940,114.

1.6 CONGESTION IMPACT GUIDELINES

1.6.1 OVERVIEW OF CONGESTION IMPACT

We have now determined the impacts of various traffic maintenance and construction methods on congestion and user cost during the project, following this sequence:

- Use the Input Sheet to estimate and record project variables that impact traffic impact and user cost, particularly for the method of traffic maintenance by which the work would typically be done, which we often call the Standard Method or Standard Case.

- If we want to consider multiple alternate routes, or if the alternate route is complex, we use the Route Sheet to calculate equivalent values for input into the Summary View.

- Enter values in the Summary View of the Traffic Sheet for the Standard Method and calculate traffic and user cost impact for each day of construction. Generally, we print the Overall View for each computer run. This allows us to study the impact in detail, to understand traffic impact for each hour of a day's construction. If the traffic and user cost impacts are acceptable, we can stop our study here. However, we might still go a little further, to see if some small adjustments might reduce impacts even further.

- We identify alternative methods of maintaining traffic during construction, and for each of them we estimate and enter values in the Summary View and we calculate and study their impacts.
- If we expect the different methods of maintaining traffic can impact construction contract cost, we use the Construction Cost Sheet. We use this as a guide and a calculator for our estimation of construction costs for alternative traffic maintenance and construction methods.
- We copy traffic, user cost, and construction cost impacts from the Summary View(s) and Construction Cost Sheet(s) to the Impact Sheet. For each method, this calculates and reports overall daily traffic and user cost impact for each day of construction and total traffic, user cost, and construction cost for the complete project.
- We use the results from earlier calculations to help us identify and fine-tune alternative methods, for each of which we calculate impacts as described above.
- To our earlier knowledge of project needs, we add what we learn from our CO^3 study of the project. We apply our engineering judgment to all we know about the project, including what we have learned using CO^3. We select a traffic maintenance and construction method that has a good, acceptable, practical balance among construction needs and costs and traffic and user cost impact.

The results in the Impact Sheet in Fig. 1-15, which are from the Example Problem for the overlay of a four-lane road, provide an example of CO^3 output. The methods identified are the following:

Method 1 – "7A-5P" – This is the Standard Method: Close a lane and work 10 hours per day, from 7A-5P each day.

Method 2 – "7A-5P, publicity" – Same as Method 1, except develop a public information program to tell users the days and hours of construction and identify alternative routes.

Method 3 – "7A-3P, publicity" – Same as Method 2, except close a lane and work 8 hours per day, from 7A-3P each day, to avoid afternoon rush hour.

Method 4 – "night, 8P-6A" – Close a lane and work 10 hours per day, but at night, from 8P-6A, when traffic is light.

Our use of CO^3 has shown the Standard Method has major impact. User cost = $440,000, which is close to contract cost. The average delay for all vehicles, including diversion delay = 6.1 min, even considering those who travel the 14 hours all lanes are open, and we estimate average user cost per vehicle = $1.14. We expect daily backups of 347 vehicles, 2 miles long. This indicates we should look for a better way of doing the work.

One alternative is to introduce a public information program, which we estimate will cost the Department $16,000. It will help users decide when to divert to the alternate route or to cancel their trip if they want to avoid delays. With an informed public, more people divert, when delays would otherwise be large, so we calculate there will be no backups. The average delay is reduced by 2.4 min, to 3.7 min. If the information program has the impact we estimate, it will reduce user cost by $135,000, to $305,000.

$305,000 is still substantial, so in Method 3 we consider shortening the work day to avoid the afternoon rush hour, in addition to the public information program. This reduces daily user cost from about $25,400 to $18,907, and it reduces average delay, including diversions to 2.7 min. However, working shorter days increases the number of lane-closed days by 3.4 days to 15.4 days. User cost is lower per day, but with the increase in work days, we see user cost reduced only by $12,000 relative to Method 2, to $292,000. Working fewer hours has not only decreased the amount of productive work per day, but it has decreased the ratio of productive time (now 7 hr/day) to time to close and open lanes (1 hr/day). This has increased estimated construction cost by $6,000.

A possible alternative is nighttime work, when traffic is light, which is described in Method 4. We estimate nighttime productivity is 0.95 relative to daytime, which increases the length and cost of construction a little, to 12.7 days and $533,000 (versus 12.0 days and $500,000 for daytime). There are no backups. A few vehicles are expected to cancel or divert their trips, just on hearing there is construction, but their impact is small. User cost, without a public information program, has been reduced to $54,000, and average delay is 0.6 min.

We now have sufficient information to compare methods. The Standard Method has major impact, which we would very much like to avoid. The public information program helps reduce impact, and we hope the public also will appreciate the concern demonstrated by the program. However, there is still a large impact. Method 3 requires the contractor to work fewer hours each day to avoid rush hour, which we calculate will provide only a small benefit. In fact, with small changes in our estimates of input values, the benefit might disappear. Certainly, the benefit is not large enough that we would want to introduce complex Special Provisions into the contract to enforce contractor compliance. Therefore, we should discard Method 3. Nighttime work obviously brings traffic and user cost impact to a low and quite acceptable level. We expect that few users would complain about its impact on traffic. If it otherwise satisfies project constraints, nighttime construction is the preferred method. If work is to be done during the day, the public information program should be developed.

1.6.2 ACCURACY AND SENSITIVITY ANALYSIS

$CO^{3,}$ is a tool we can use to improve our project decisions. It can estimate the impact of different traffic maintenance and construction methods at the first stages of project consideration, when a project is still ill defined. CO^3 accuracy is a function of the accuracy of our input estimates, some of which may be quite rough estimates, such as the effect of delays on traffic behavior. We should not be overly concerned with the absolute accuracy of CO^3, because its purpose is not to provide precise estimates but to provide for good decisions. We expect its estimates of traffic behavior and user cost and construction cost are no better than ±10%, which is sufficiently accurate for good engineering decisions.

We use CO^3 to shape a project in a form that will save miles of daily backups and hundreds of thousands (even millions) of dollars of user cost, and will support reasonable and safe driver behavior. These broad decisions depend on a better understanding of project behavior, not on precise values of sensitive information.

Sensitivity analysis is calculation of differences in output due to differences in input. We can use sensitivity analysis, informally or formally, to help us apply engineering judgment to CO^3 results and related project decisions. In formal sensitivity analysis, we input different values of input variables into our calculations to determine the impact that changes in input have on output and decisions. We can apply sensitivity analysis to any quantitative variables. Most typically, we change one variable or one set of related variables at a time to understand their impact. An example is shown in the Example Problem. Even more important is our informal sensitivity analysis, in which we sit back and think through the relationships among variables, we identify possible inaccuracies, and we predict their impact on our decisions. This allows us to view CO^3 input and output and decisions from the perspective of the overall project, so we develop a realistic view of project behavior and make reasonable and practical project decisions.

1.6.3 OTHER TYPES OF CLOSURES

1.6.3.1 Detours or Total Closure

Closing a road changes the primary path for vehicles that travel the road. If a detour is used to handle only the traffic that would travel the road, the design demands used for the road are applicable to the detour, and cancelled traffic and diverted traffic to an alternate route (other than the detour) should be estimated and input as with the regular road.

However, when traffic is rerouted to use one or more routes that already carry traffic, total traffic includes the traffic already traveling on the other route(s). For example, if a work zone 4P-5P design demand = 1354 VPH is forced onto another road that typically has 4P-5P demand = 780 VPH, the model must use input 4P-5P design demand = 1354 + 780 = 2134 VPH on that other road. Calculating actual demand on the new route also depends on input of cancelled and diverted traffic for the total design demand.

If the user only wants to calculate the impact of differing distance and speed on the closed road's traffic, the user can input values for method travel distance and speed and normal travel distance and speed, and the model will calculate the delay on the closed road's traffic. In addition, the user can calculate backup impact if the user inputs the excess capacity of the second road as the primary path capacity.. For example, if estimated capacity = 1400 VPH for the road above that has 4P-5P demand = 780 VPH, the road's 4P-5P excess capacity = 1400 - 780 = 620 VPH. The original road 4P-5P design demand leaves 1354 - 620 = 734 VPH at 4P-5P for which the model calculate will backed up, cancelled, and diverted traffic in the usual way. However, the calculated delays are a low estimate for total impact, because they do not include the impact of the closed road's traffic, other than backup, on the substitute road's original traffic.

When more than one route will carry the added traffic, as may happen when the road is closed without a specified detour, the user can estimate the amount of traffic that would be added to each route and calculate traffic impact and user costs for all the traffic that travels each route. These can then be summed to calculate the overall impact. Alternatively, the user can add the capacities and demands of the routes to determine the overall impact of the rerouted traffic, on the assumption that the rerouted traffic will spread itself over the available capacity.

1.6.3.2 Ramp closing

Just like any road, traffic that reroutes to another ramp adds to the demand at that ramp and on the road(s) to that ramp. Some overall traffic diverts to other route(s). Capacity of an on-ramp can vary with the demand/capacity of the road it serves. Less generally, capacity of an off-ramp can also vary with the demand/capacity of the road it serves.

1.6.3.3 Alternating Traffic in One Lane – Flagging

Suppose that instead of a four lane roadway, a project consists of bituminous overlaying of a two lane roadway. Commonly, one lane would be closed to traffic while the remaining lane would handle both directions of travel using some alternating, flagging system. This scenario is not modeled by CO.xls and its Traffic Sheet, because capacity in both directions, simultaneously, varies according to the length of time a gate is open (See "Alternating Traffic in One Lane", Carr 1996). Instead, it is modeled in a parallel CO^3 Program, COFlag.xls. Chapter 4 describes the special characteristics of COFlag.xls and its variables.

The components in CO.xls have equivalents in COFlag.xls:

- CO.xls Traffic Sheet ⇒ COFlag.xls Flag Sheet
- CO.xls Input Sheet ⇒ COFlag.xls Flag Input Sheet
- CO.xls Route Sheet ⇒ COFlag.xls Flag Route Sheet
- The following sheets are the same in both programs:
  - Construction Cost Sheet
  - Impact Sheet
  - Daily Cost Sheet

1.6.4 CAPACITY AND DEMAND DIFFER FROM POINT TO POINT

1.6.4.1 Determining the Bottleneck

Entering and exiting vehicles at ramps of limited access roadways or intersections of free access roadways can cause demand to vary from point to point within a work zone. Changes in number of lanes, location of work, or other characteristics within a work zone can cause capacity to vary from point to point. The bottleneck situation at which design demand and capacity produce the greatest traffic impact and user cost is usually obvious. The bottleneck condition is usually that at which maximum demand is greatest relative to capacity. If we are not sure which is the bottleneck condition, we calculate traffic impact and user cost for each possible bottleneck to determine that which produces the greatest impact.

Example: Smith Road Eastbound demand East of Jones Road is always greater than Eastbound demand West of Jones. Capacity is the same on both sides of Jones. Therefore, for a 6-day Smith lane closure that extends both East and West of Jones, we use Smith Eastbound design demand and capacity for all 6 days..

If design demand or capacity change significantly as work moves within a work zone or as the work zone moves along a route, we must separately analyze traffic impact and user cost for the days of each scenario. In a variation of the example above, if lane closure is 3 days East of Jones, followed by 3 days West of Jones, then total Eastbound impact is impact for 3 days of design demand and capacity East of Jones plus impact for 3 days of design demand and capacity West of Jones.

1.6.4.2 Signaled Intersections

In general, a route with signaled intersections is handled no differently from other routes. Signals reduce capacity below what it would be with no signals, so a route with signals has less capacity than if it had no signals. A route with multiple signaled intersections has less capacity than if it had a single signaled intersection. Determining capacity of a route with signaled intersections is a traffic engineering problem, but we expect a route with signals to have roughly half the capacity it would have with no signals.

1.6.5 GUIDELINES FOR CO^3 SCOPE DECISIONS

1. CO^3 is a tool we use to help us exercise engineering judgment and make good engineering decisions. It it expands our capabilities and allows us to explore alternative scenarios, outcomes, and alternatives. It makes better use of what we know and what we can do, it does not replace it.
2. We use CO^3 at the earliest stages of project consideration to estimate traffic and user cost impacts of construction. All CO^3 requires is a traffic count and identification of method(s) of maintaining traffic during construction and expected diversion route(s). Knowing the method and diversion route, we then estimate work zone capacity, speed, and distance; diversion percentages, speed, and distance; cancellation percentages. CO^3 calculates hourly and daily impact for all alternatives we identify.
3. We estimate project duration, from which CO^3 estimates total project user cost using the Construction Cost Sheet. We estimate contract cost, and differences in construction variables for alternative methods, and CO^3 calculates differences in contract cost for the alternative methods. By manual calculations or the Impact Sheet, we compare project traffic impacts, user costs, and construction for alternative methods. We also use CO^3 user costs and construction costs as input to life cycle cost analysis of projects.
4. Therefore, CO^3 helps us select an acceptable and practical method when we first scope the project. It helps us update and track changes as the project moves from scope to implementation, it helps us determine contract period costs for special provisions and actual period costs with which to adjust contract amount at project completion.
5. We select, scope, and design projects to be constructed in the future. We must make intelligent, practical decisions, though we do not know exactly what will actually occur in the future. Therefore, we base our decisions on our predictions of the future, which we call estimates. For the most part, we must base our estimates of the future on what we know of the past. However, we cannot let the objective nature of past experience override our engineering judgment of what we expect to occur in the future. Therefore, in estimating the future, we apply what we know of the past to what we can anticipate for the future.
6. We must estimate the value of every variable, regardless of our level of uncertainty. Though we may be tempted to just use a value of zero (or leave the value "blank" on $MCon^2$ input), we must not do so unless our best estimate of the value is indeed zero. Otherwise, our $MCon^2$ output and our decisions will be based on information we know is incorrect. Therefore, when we know a value is not zero, we cannot input zero (or leave it blank).

   Example: We know traffic has increased over the past five years on a particular road, we expect growth will continue, but we are quite uncertain on the future rate of growth. We cannot dodge the estimate by inputting annual traffic growth = 0 (or leaving it blank). If we expect it will grow at least 2%/yr but not more than 5%/yr, and out best estimate is 3%/yr, we input 3%/yr. We can also try various values between 2%/yr and 5%/yr to determine how sensitive the output and our decision is to the rate of growth.

Similarly, it can be difficult to estimate the fraction of vehicles that will cancel their trips or divert to an alternate route. Our estimating may be quite rough, but it is far better than just turning our backs on the problem, which is equivalent to estimating that no vehicles cancel or divert. In particular, if no vehicles cancel or divert, all demand must pass through the zone, which can produce quite large backups. We are not sure exactly how many vehicles will cancel or divert, but we can be sure there will be a significant number if the alternative is long backups.

7. We commonly use expected values (which we often call average values) for estimates of future traffic impacts and user costs from construction projects. For most estimates, we informally apply our engineering judgment to arrive at our best estimate, without performing explicit calculations. However, we define expected value by a general equation for $\bar{x}$ = expected value of x, where x_i = value of possible outcome i, which has $P(x_i)$ = probability that outcome x_i occurs:

$$\bar{x} = \sum_{i=1 \text{ to } N} x_i * P(x_i) \tag{23}$$

Example: We estimate there is a 0.2 probability that the Department will have to resurface an alternate route, for which we estimate the resurfacing cost = $40,000, and there is a 0.80 probability the Department will not need to resurface an alternative route. Expected value = $40,000 * 0.2 + 0 * 0.8 = $8,000.

Example: We estimate traffic growth on State St. will be 3% with probability 0.4 and 4% with probability 0.6. Expected value of traffic growth = 3% * 0.4 + 4% * 0.6 = 3.6%.

8. We should implement public information programs whenever users will benefit, even if analysis does not establish the user costs it saves greatly exceed its implementation costs. Public information is a generally inexpensive way we can reduce project impact and at the same time interact with users and to better serve our public. And unlike specifying period costs in Special Provisions, we reduce project impact without interfering or impacting contractors' project management.

9. We determine poor times for construction lane closures, and we avoid them if possible. Many roads are impacted by a county fair, football game, season or product festival, golf tournament, special holiday, hunting or fishing season, weekend traffic, commuter traffic, etc. Such events can often be avoided without any impact on project cost.

1.7 USING CO^3 TO CALCULATE PERIOD COST

1.7.1 CONTRACT PERIOD COST

Project implementation includes selecting clauses and values to include in Special Provisions for Maintaining Traffic (which we call Special Provisions, for short). Contract period cost, or period cost, is the term we use for such values specified in the Special Provisions for contract costs per time period, particularly contract cost for periods in which construction impacts traffic. Contract period cost can be shown in a contract in various forms, including as incentives or disincentives, adjustment values for A + B contracts, and rent-a-lane charges. The basis for selecting contract period cost for a project is user cost caused by construction during the relevant periods.

Period cost can differ from user cost in several ways:

- Most important, period costs stated in a contract are usually a fraction of user cost.
- Period cost is often the same for both directions, based on the average of the user costs of two directions of travel.
- Period cost is often rounded off to tens or hundreds of dollars per period.
- Period cost is often specified for periods that are a fraction of an hour, particularly period lengths of 15 min, 20 min, or 30 min.

We need the CO^3 Computer Program to calculate user cost. But a computer is often not available to calculate user cost and period cost in the field, and including a complex computer program and its calculations within contract Special Provisions is probably not practical. Therefore, the CO^3 Daily Cost Sheet (daily tab) calculates tables that can be inserted into project reports, proposals, and Special Provisions and used by the Department, contractors, and other contract administrators and project managers to calculate contract period cost to determine contract amount for budgeting, competitive bidding, and contract payment.

1.7.2 DAILY COST SHEET (DAILY TAB)

1.7.2.1 General

The Daily Cost Sheet calculates daily traffic user cost for any set of traffic maintenance hours, for any cost round-off and for fractions of periods. In this *CO^3 User manual*, we call it the Daily Sheet for brevity, and it is the "daily" tab in the CO^3 Computer workbook. The purpose of the Daily Sheet is to provide useful tables for reporting user cost and period cost, from which we can easily calculate user cost and period cost for different combinations of lane-closed periods without having to run the CO^3 computer program. This provides us with methods by which we can print and distribute tables of project user cost and period cost, from which people can easily calculate user cost without using a computer. In addition, the Daily Sheet calculates total project user cost and period cost for the actual lane closures experienced during the duration of a project. The Daily Sheet contains five views:

- **User Cost View**, in which we input and report user cost for each hour and a portion of an hour (see Fig. 1-16)
- **Period Cost View**, which shows period costs as a rounded-off fraction of user cost (see Fig. 1-19).
- **Detailed Cost View**, from which we can more easily manually calculate period cost for time periods, including fractions of periods (see Fig. 1-21).
- **Daily Cost View**, which is an even more detailed view of period cost, which includes a table of all possible traffic maintenance hours (see Fig. 1-22).
- **Project Cost View**, in which we enter the actual periods a lane was closed during construction, and CO^3 calculates the period costs that occurred each day and their sum for the completed project (see Fig. 1-24).

Each Daily Sheet shows period cost for each of 24 hours of lane closure, including fractions of an hour. Therefore, one Daily Sheet can report period cost for one type of traffic maintenance, without regard to the particular hours of lane closure. For example, the views of the Daily Sheet shown here report lane closure period cost for the Standard Method, in which a single lane is closed without a public information program that announces lane closures in advance. Method 1, "7A-5P" in the Summary View of Fig. 1-6 is one example, for 7A-5P lane closures. A different

Daily Sheet would be needed to show period cost for lane closure with the public information program.

1.7.2.2 User Cost View

The User Cost View, which is also called the User View, has two basic functions: it is the table in which we input user cost from which period cost is calculated in the Daily Sheet, and it provides a simple table for reporting user costs. Fig. 1-16 shows an example, for user cost for each of 24 hours and for 15 minute periods. The User Cost View is at the top-left of the Daily Sheet, and Fig. 1-16 shows the top-left of the Daily Sheet, as well as the User Cost View. At the top-left is a list of the five views in the Daily Cost Sheet, with a set of buttons we can L-click to go to the top-left of another view:

Daily Cost Sheet Tables	
User Cost View	Go To
Period Cost View	Period Cost
Detailed Cost View	Detailed Cost
Daily Cost View	Daily Cost
Project Cost View	Project Cost

For example, we can L-click on Daily Cost to go to the top-left of the Daily Cost View. Similar navigation buttons are placed at other convenient places in the Daily Sheet, which are shown in the other Daily Sheet Views (Fig. 1-21, Fig. 1-22, Fig. 1-24, and Fig. 1-25).

User View input cells are light yellow on the computer and light gray in printed output. In addition to project identification information, there are four input variables:

- **Method**, which identifies the traffic maintenance method for which user costs were calculated, such as “No Publicity” or “Weekday” or “One Lane Each Way.” This is generally related to the method identifier in the Traffic Sheet.
- **Traffic** status for which user costs were calculated, such as “Lane-Closed” or “Lane Open.” This is generally related to the closure status in the Traffic Sheet.
- **User cost** for each hour for the traffic maintenance method and traffic status. This is generally taken directly from a computer run of the Traffic Sheet for 24 hours of the traffic maintenance method and traffic status.
- **Period** = the smallest fraction of an hour for which period cost will be calculated and reported, which is usually 15 min, 20 min, or 30 min or it may be left blank (by punching Delete key).

Generally, we directly Copy and Paste Value hourly user cost from a computer run of the Traffic Sheet. Fig. 1-16 **other** project input shows the source of user costs is “From avg traffic sheet: M1”. We can also adjust hourly user costs to include impact costs that are not included in or differ from those calculated on the Traffic Sheet. For example, we can add impact costs due to inconvenience or loss of business to businesses or other property owners adjacent to or otherwise served by the road or its alternate routes or detours. If we calculate period cost someplace other than in the Period Cost View, we manually enter those period costs in the user cost column of the User Cost View, as discussed below in Sec. 1.7.2.4.

Fig. 1-17, shows a Combined View for a computer run of the Traffic Sheet for 24 hours for the Standard Method in which there is no public information program (identified as “No Publicity”) for hours of closure (identified as “Lane Closed”). The data which were input into the

Summary View are shown in this Combined View. The data are the same as for the lane-closed periods, 7A-5P, of the "7A-5P" method shown in the Summary View in Fig. 1-6 on pg. 1-27, except for the following differences.

- historical demand in Fig. 1-17 is the average of the historical demand in both directions in Fig. 1-6.
- capacity in Fig. 1-17 is 1400 VPH for all 24 hours, because we are calculating user cost for each hour for the lane being closed all 24 hours.

Therefore, the Combined View shows output for each hour for a lane closed 24 hours for the average of the design demand in both directions. We Copy all 24 hours of the "user cost" column from the Combined View of the Traffic Sheet and Paste-Value it into the User View of the Daily Sheet. We hit F9 to calculate, and CO^3 calculates the values in all five views of the Daily Sheet. For the User View, output is the user cost for each fraction of an hour, for 15 min periods in Fig. 1-16. We can print the User View by clicking the Print button.

Daily Sheet calculations assume the user cost for each hour of lane closure does not depend on whether the lane is closed adjacent hours. This is correct when there are no backups. We still use the Daily Sheet for periods that have backup, even though period cost in one period depends on lane closures in other periods, for two reasons:

- Our estimates of traffic impacts are only approximations of actual traffic behavior and user cost, and we set contract period cost an arbitrary amount lower than user cost. Therefore, we are not particularly concerned with small inaccuracies in user cost results.

- Each hourly user cost in the Daily Sheet assumes the lane is also closed in adjacent hours. Lane closures are usually many hours long, typically an entire working day or 24 hours. Therefore, the assumption is true for most hours, though not necessarily for those that start and end a lane closure.

Daily Cost Sheet Tables

User Cost View	**Go To**
Period Cost View	Period Cost
Detailed Cost View	Detailed Cost
Daily Cost View	Daily Cost
Project Cost View	Project Cost

User Cost View **Paste Values**

Project:	US 00 Overlay (Example)	
By:	R. I. Carr, 7/1/97	
Other:	From avg traffic sheet: M1	
Method:	No Publicity	
Traffic:	Lane Closed	
Print	User Cost per Period	
Period (min):	60	15
12 A - 1 A	$193	$48
1 A - 2 A	$95	$24
2 A - 3 A	$56	$14
3 A - 4 A	$29	$7
4 A - 5 A	$32	$8
5 A - 6 A	$44	$11
6 A - 7 A	$250	$62
7 A - 8 A	$2,088	$522
8 A - 9 A	$4,509	$1,127
9 A - 10 A	$2,967	$742
10 A - 11 A	$2,319	$580
11 A - 12 P	$2,885	$721
12 P - 1 P	$3,804	$951
1 P - 2 P	$3,672	$918
2 P - 3 P	$3,729	$932
3 P - 4 P	$4,360	$1,090
4 P - 5 P	$5,889	$1,472
5 P - 6 P	$6,917	$1,729
6 P - 7 P	$5,042	$1,260
7 P - 8 P	$2,279	$570
8 P - 9 P	$1,442	$360
9 P - 10 P	$1,318	$329
10 P - 11 P	$719	$180
11 P - 12 A	$346	$86
24 hr	$54,983	

Fig. 1-16 Daily Sheet User Cost View

Combined View

period length (min)	60	
annual traffic growth (%)	0	
years of growth	2	
VEHICLE INPUT	**cars**	**trucks**
design demand (%)	90.0%	10.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION	
PROJECT	US 00 Overlay
TITLE	Example Problem
C.S.	90000
JOB #	00000
START DATE	6/00/98

REPORT INFORMATION	
REPORT	DETAILED USER COST REPORT
TITLE	COMBINED VIEW
DIVISION	
REPORT BY	R. I. Carr
REPORT DATE	1/2/97

NOTES:

METHOD INPUT		METHOD 1	
method title		24 hr, Not Announced	
DISTANCE AND SPEED	(mi) (mph)	distance	speed
work zone	method travel	2	see delay
	normal travel	2	65
diversion	method travel	12	50
	normal travel	10	65
SPEED DELAY		threshold	range
capacity for speed delay (V/period)		1400	
speed (when D~0) (mph)		45	
speed (when D=C) (mph)		10	
DECREASE TO DEMAND		threshold	range
capacity for decreases to design demand (V/period)		1400	
canceled cars (with no delay) (%)		5.0%	
canceled trucks (with no delay) (%)			
canceled cars (with delay) (%/min)		1.0%	
canceled trucks (with delay) (%/min)			
diverted cars (with no delay) (%)		5.0%	
diverted trucks (with no delay) (%)			
diverted cars (with delay) (%/min)		1.0%	
diverted trucks (with delay) (%/min)		0.5%	
OTHER USER COST INPUT		cars	trucks
other user cost per vehicle ($/V)		$0.00	$0.00
user cost per diversion ($/V)		$1.53	$2.93

SUMMARY OUTPUT	
traffic method	24 hr, Not Announced
direction	Avg
total user cost	$54,983
user cost of delays	$42,642
user cost of decreases	$12,341
maximum backup (V)	260
maximum backup length (lane mi)	1.5
maximum delay (min.)	21.3
average delay (min)	10.5
total delay, except diversions (V hr)	3,952
total vehicles canceled(V)	4,671
total vehicles diverted (V)	4,850
total decrease in demand (V)	9,521
% decrease in demand	29.7%
delay per diverted vehicle (min)	5.2
total diversion delay (V hr)	418
average delay, including diversions (min)	9.6
total delay, including diversions (V hr)	4,370
user cost / design demand	$1.71
delay cost / actual demand	$1.89

Combo | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

Direction: Avg | backup at start (V) 0

period (hr)	capacity (V/period)	actual demand (V/period)	total decrease (V/period)	total delay (V/period)	backup eop (V)	maximum delay (min)	average backup delay (min)	average speed delay (min)	decrease cost ($)	delay cost ($)	user cost ($)	delay cost / actual demand ($/V)
12 A	1400	413	56	11	0	1.63	0.0	1.6	$72	$121	$193	$0.29
1 A	1400	261	33	5	0	1.14	0.0	1.1	$42	$54	$95	$0.21
2 A	1400	171	21	3	0	0.96	0.0	1.0	$26	$29	$56	$0.17
3 A	1400	96	11	1	0	0.86	0.0	0.9	$14	$15	$29	$0.16
4 A	1400	102	12	1	0	0.87	0.0	0.9	$15	$16	$32	$0.16
5 A	1400	140	17	2	0	0.91	0.0	0.9	$21	$23	$44	$0.16
6 A	1400	476	68	15	0	1.90	0.0	1.9	$87	$163	$250	$0.34
7 A	1400	1,192	357	151	0	7.59	0.0	7.6	$461	$1,627	$2,088	$1.36
8 A	1400	1,528	747	328	128	15.62	2.7	10.2	$969	$3,540	$4,509	$2.32
9 A	1400	1,196	490	216	0	15.62	1.7	9.2	$635	$2,332	$2,967	$1.95
10 A	1400	1,239	392	168	0	8.13	0.0	8.1	$507	$1,811	$2,319	$1.46
11 A	1400	1,341	480	210	0	9.39	0.0	9.4	$622	$2,264	$2,885	$1.69
12 P	1400	1,463	628	277	63	12.58	1.2	10.2	$814	$2,991	$3,804	$2.04
1 P	1400	1,353	606	267	16	12.86	1.7	10.2	$786	$2,886	$3,672	$2.13
2 P	1400	1,431	615	272	48	11.91	1.2	10.2	$798	$2,931	$3,729	$2.05
3 P	1400	1,445	723	317	93	14.13	3.0	10.2	$939	$3,421	$4,360	$2.37
4 P	1400	1,520	1,012	424	213	19.33	6.6	10.2	$1,315	$4,574	$5,889	$3.01
5 P	1400	1,447	1,259	489	260	21.29	10.1	10.2	$1,638	$5,279	$6,917	$3.65
6 P	1400	1,230	877	362	90	21.29	7.5	10.2	$1,140	$3,901	$5,042	$3.17
7 P	1400	1,138	382	165	0	13.99	0.7	8.1	$494	$1,785	$2,279	$1.57
8 P	1400	1,037	259	103	0	5.94	0.0	5.9	$334	$1,108	$1,442	$1.07
9 P	1400	1,002	240	93	0	5.60	0.0	5.6	$310	$1,008	$1,318	$1.01
10 P	1400	784	149	49	0	3.75	0.0	3.7	$191	$529	$719	$0.67
11 P	1400	563	86	22	0	2.32	0.0	2.3	$110	$235	$346	$0.42
TOT	33600	22,568	9,521	3,952					$12,341	$42,642	$54,983	$1.89
MAX	1400	1,528	1,259	489	260	21.29	10	10.15	$1,638	$5,279	$6,917	$3.65
MIN	1400	96	11	1	0	0.86	0	0.86	$14	$15	$29	$0.16

Fig. 1-17 Combined View of “24 hr, Not Announced”, Average Traffic

1.7.2.3 Manual Calculations

The general equation for manual calculation of user cost or period cost for period j through period k is the following:

$$(cost)_{j \text{ to } k} = \sum_{i=j \text{ to } k} (cost)_i \qquad (24)$$

and for any group of lane-closed periods i = 1 to N,

$$(cost)_{N\ \text{periods}} = \sum_{i=1\ \text{to}\ N} (cost)_i \qquad (25)$$

Therefore, we can calculate the user cost for a lane being closed several adjacent periods by summing the periods' user costs. Our usual procedure is the following:

1. Compute each period's user cost on the Traffic Sheet for lane closure all 24 periods.
2. Sum each period's user cost in accordance with Eq. (24).

Fig. 1-17 is an example of step 1. Its user cost column as an example of step 2. The user cost for a lane being closed from 1P to 4P = (1P-4P user cost) = (1P-2P user cost) + (2P-3P user cost) + (3P-4P user cost) = 3,672 + 3,729 + 4,360 = $11,761. This demonstrates that we can calculate user cost directly from the Traffic Sheet for any set of lane-closed hours.

1.7.2.4 Period Cost View

The Period Cost View, which is also called the **Period View**, of the Daily Sheet calculates period cost for each hour and smallest period of an hour as a rounded-off fraction of user cost, and it provides results in a simple format that is practical for printing in reports. The Period Cost View has four inputs, all of which are included in "Period Cost Input". These are shown in Fig. 1-18.

- **P/U fraction** = P/U = fraction of user cost that will be included in period cost (see Sec. 1.8, pg. 1-81. For example, for P/U = 40%, period cost = (40%) * (user cost).
- **cost threshold** = calculated period cost below which period cost will be set to zero. For example, if cost threshold = $100, any period cost that would be less than $100 will be set to zero.
- **hourly cost round-off** (which is above the 60 min column) = dollars at which hourly period costs are rounded-off.
- **period cost round-off** (which is above smallest period column) = dollars at which period costs are rounded-off for periods that are a fraction of an hour. This should never be greater than hourly cost round-off.

Also shown in Fig. 1-18 are comments that accompany these worksheet cells. At the top-right of some cells is a small red triangle (black in this report) that indicates the cell contains a comment that provides an explanation or instructions to worksheet user. Whenever we place the cursor over the cell, the comment appears. For example, we will see the comment box that contains "Default = 1 for user ----" whenever we place the cursor over the top of the cell that contains "40.0%" in Fig. 1-18.

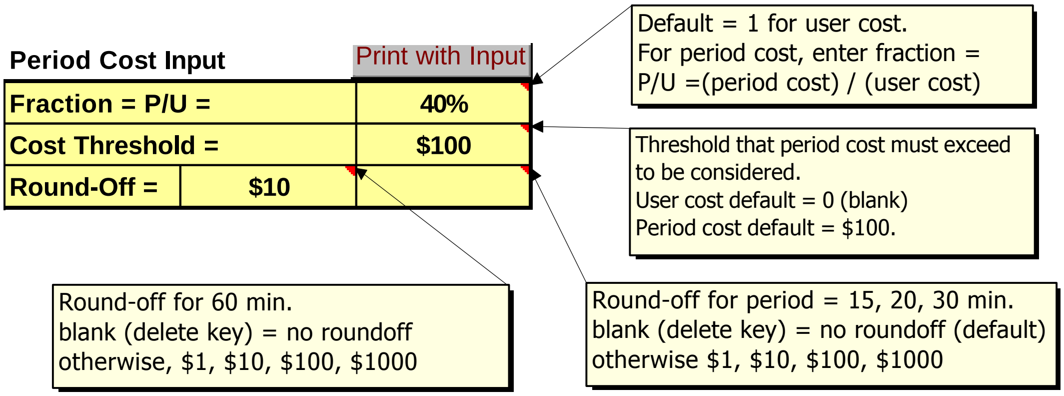

Fig. 1-18 Input to Period Cost View, Showing Comments in Cells

As we discuss later in Sec. 1.8 on contract Special Provisions, we generally set period cost to be a fraction of user cost, such as 40% of user cost. We input this fraction into the Period Cost View to calculate period cost as a fraction of user cost. In addition, we can round-off hourly period costs or period costs of a fraction of an hour to tens or hundreds of dollars. For example, we follow the following assignment pattern for round-off, for a value of $4,347.683--:

- blank (push Delete key) = no round-off ($4,347.683-- remains $4,347.683--)
- $1 = round-off to closest $1 ($4,347.683-- becomes $4,348).
- $10 = round-off to closest $10 ($4,347.683-- becomes $4,350).
- $100 = round-off to closest $100 ($4,347.683-- becomes $4,300).

To report user cost without adjustment for all views of the Daily Sheet, select the following values (which we call **null values**) for the Period Cost View that do not that adjust user cost.

- input P/U = 1
- cost threshold = 0 (or blank)
- hourly cost round-off = blank
- period cost round-off = blank

Fig. 1-19 shows the Period View calculated from user costs shown in the User View of Fig. 1-16, based on period cost = P/U = 40% of user cost, for which hourly costs are rounded-off to tens, but fractions of hours are not rounded-off. The Period View has two print buttons. Print with Input prints the table, with the Period Cost Input table. Print prints the Period View without the input table.

In accord with Eq. (24), we can manually calculate period costs for any lane closure periods by summing the period costs of the time periods. For example, from Fig. 1-19, (12:45P-4:30 period cost) = (12:45P-1P) + [(1P-4P) = (1P-2P) + (2P-3P) + (3P-4P)] + (4P-4:30P) = 380 + [1,470 + 1,490 + 1,740 = 4,700] + (2 * 590 = 1,180) = $6,260.

The Period Cost View can be used by the Department at any stage of project implementation, and we can include it in contract bidding documents, from which bidding contractors can calculate period cost as part of their project estimating process. We can Copy and Paste it into a word processing document as described in Sec. 1.3.2.5, pg. 1-5. It can also be inserted in Special Provisions, for contract administration purposes. We can also easily change its format for such applications. For example, we can delete project titles and information on its preparation. We can add a title, such as "Liquidated Damages", which is appropriate to its application.

The Period Cost View may show more information than we want in a table of period costs in contract Special Provisions. Fig. 1-20 shows two versions of lane closure period cost tables whose values were taken from Fig. 1-19. Time periods with period cost = 0 are not shown. The table on the right identifies the traffic condition to which it applies, which is needed when the period cost depends on traffic condition.

All period costs calculated by the Period View share the same P/U, cost threshold, and round-off. On some projects, we may want use the Detailed View, Daily View, and/or Project View for period costs that are determined in another manner. For example, to discourage but not prohibit all nighttime work on a project, we can select contract period costs for nighttime hours that are a higher fraction of user cost than for daytime hours. We can manually enter period cost in the User View of the Daily Sheet, in the 60 minute column. We then enter null values for Adjustments to User Cost above the Period View, so the period costs entered in the User View are not changed by Period View calculations.

We could manually enter period costs directly in the Period View. We prefer not to, because the manually entered values replace the equations in the Period View cells, and we want to avoid corrupting a worksheet.

1.7.2.5 Detailed Cost View

The Detailed Cost View, which is also called the **Detailed View**, provides a table of period costs from which we can easily calculate period cost for any set of lane-closed periods. Fig. 1-21 shows the Detailed View that CO^3 calculated from the Period View of Fig. 1-19, including example calculations that guide the user in making manual calculations. The Detailed View shows the period cost for each hour and for each fraction of an hour, based on the fraction of an hour that we input into the User View. It also shows the sum of hourly period costs, starting at midnight. Example calculations are shown for whichever fraction of an hour period costs are calculated: 15 min, 20 min, or 30 min. The Detailed View has two print buttons. [Print w/ Examples] prints the table, with the example calculations below it. [Print] prints the table without the examples.

The Detailed Cost View can be used by the Department at any stage of project implementation. As discussed for the Period Cost View, it is suitable for contract bidding documents and Special Provisions, from which contractors and project administrators can calculate period cost. We can also easily change its format or titles for contract documents. We can delete the reference to P/U, if we feel it is inappropriate for contract documents.

Using Eq. (24), the two basic methods of manually calculating period costs from the table are the following:

- Sum the hourly period cost and add additional fractions. For example, (12:45P-4:30 period cost) = (12:45P-1P) + [(1P-4P) = (1P-2P) + (2P-3P) + (3P-4P)] + (4P-4:30P) = 380 + [1,470 + 1,490 + 1,740 = 4,700] + 1,180 = $6,260.
- Subtract the table "Sum" of the earlier time from the "Sum" of the later time, and add period cost of periods that are less than one hour. For example, (12:45P-4:30 period cost) = (12:45P-1P) + [(1P-4P) = (12A-4P) – (12A-1P)] + (4P-4:30P) = 380 + [12,130 – 7,430 = 4,700] + 1,180 = $6,260.

1.7.2.6 Daily Cost View

The Daily Cost View, which is also called the **Daily View**, of the Daily Sheet provides a view of period costs that is even more broad than the Period Cost View. It consists of three major sections:

- **Short Term Daily Cost Table**, which shows period cost for each hour and fraction of an hour.
- **Long Term Daily Cost Table**, which shows period cost for any combination of whole hours of lane closure, plus amounts to add to accommodate additional fractions of hours.
- **Example** calculations, which show examples of manual calculations involving the Short Term and Long Term tables.

Fig. 1-22 shows the Daily View that is calculated from the values shown in the Period View shown in Fig. 1-19. The most important segment of the Daily View is the central rectangular area of the Long Term Table. This segment is shown separately in Fig. 1-23. Across its top and bottom and down its left and right sides are the 24 hours of a day. At each intersection of a row and column is the period cost for a lane closure that starts at the time down the side and ends at the time across the top and bottom. For example, to find the period cost of a 7A-5P lane closure, we look at the intersection of the 7A row and the 5P column, where we read 7A-5P period cost = $14,490 per day.

The diagonal from top-left to bottom-right, under the stepped line, shows period cost of a 24 hour lane closure, $21,730. Every diagonal shows the period cost of a lane closure of a particular length that starts and finishes at different times. For example, 8A-6P period cost = $16,420 is below and right of 7A-5P period cost = $14,490.

Therefore, the Daily View supports quick and easy calculation and comparison of period costs of lane closures that start at different times and that have different lengths. In addition, we can easily manually calculate differences in costs of closing or opening a lane at times other than on the whole hour. Examples of such calculations are shown at the bottom of the Daily View. These calculations depend on the period cost of fractions of an hour, which are shown in the Short Term Table and down the left side and across the bottom of the Long Term Table.

The Short Term Table is handy for determining the period cost of short length lane closures. For example, a 1:15P-2:00 lane closure is 45 min between 1P and 2P. In the Short Term Table, we look under "1-2" in the center of the top row, where the 1-2 column intersects the "45" row, and we read $1,103, which is the 1:15P-2:00P period cost.

Period Cost Input Print with Input

Fraction = P/U =		**40%**
Cost Threshold =		**$100**
Round-Off =	**$10**	

Period Cost View

Project:	US 00 Overlay (Example)	
By:	R. I. Carr, 7/1/97	
Other:	From avg traffic sheet: M1	
Method:	No Publicity	
Traffic:	Lane Closed	
Print	Cost per Period	
Period (min):	60	15
12 A - 1 A	$0	$0
1 A - 2 A	$0	$0
2 A - 3 A	$0	$0
3 A - 4 A	$0	$0
4 A - 5 A	$0	$0
5 A - 6 A	$0	$0
6 A - 7 A	$0	$0
7 A - 8 A	$840	$210
8 A - 9 A	$1,800	$450
9 A - 10 A	$1,190	$298
10 A - 11 A	$930	$233
11 A - 12 P	$1,150	$288
12 P - 1 P	$1,520	$380
1 P - 2 P	$1,470	$368
2 P - 3 P	$1,490	$373
3 P - 4 P	$1,740	$435
4 P - 5 P	$2,360	$590
5 P - 6 P	$2,770	$693
6 P - 7 P	$2,020	$505
7 P - 8 P	$910	$228
8 P - 9 P	$580	$145
9 P - 10 P	$530	$133
10 P - 11 P	$290	$73
11 P - 12 A	$140	$35
24 hr	$21,730	

Fig. 1-19 Daily Sheet Period Cost View

We use the Long Term Table to determine the period cost of longer duration lane closures. Down the left side of the Long Term Table are the additional period costs of closing a lane earlier than the whole hour to its right. For example, closing a lane 30 min earlier than 9A has a period cost $900 greater than closing the lane at 9A, as we see in the "+ :30" column to the left of "9A". Similarly, keeping a lane-closed 45 min later than 6P has a period cost $1,515 greater than opening the lane at 6P, as we see in the "+ :45" row below "6P" at the bottom of the Long Term Table. Therefore, we can read a computer print-out of the Long Term Table to easily compare the period costa of alternative lane closing patterns, without making computer runs.

Lane Closure Period Costs

Lane Closure:	Not Announced, Lane Closed = NC	
	Cost per Period	
Period (min):	60	15
7 A - 8 A	$840	$210
8 A - 9 A	$1,800	$450
9 A - 10 A	$1,190	$298
10 A - 11 A	$930	$233
11 A - 12 P	$1,150	$288
12 P - 1 P	$1,520	$380
1 P - 2 P	$1,470	$368
2 P - 3 P	$1,490	$373
3 P - 4 P	$1,740	$435
4 P - 5 P	$2,360	$590
5 P - 6 P	$2,770	$693
6 P - 7 P	$2,020	$505
7 P - 8 P	$910	$228
8 P - 9 P	$580	$145
9 P - 10 P	$530	$133
10 P - 11 P	$290	$73
11 P - 12 A	$140	$35
Total	$21,730	

Liquidated Damages

	Cost per Period	
Period (min):	60	15
8 A - 9 A	$1,800	$450
9 A - 10 A	$1,190	$298
10 A - 11 A	$930	$233
11 A - 12 P	$1,150	$288
12 P - 1 P	$1,520	$380
1 P - 2 P	$1,470	$368
2 P - 3 P	$1,490	$373
3 P - 4 P	$1,740	$435
4 P - 5 P	$2,360	$590
5 P - 6 P	$2,770	$693
6 P - 7 P	$2,020	$505
7 P - 8 P	$910	$228

Fig. 1-20 Period Cost Tables in Formats for Special Provisions

We can print the view with or without examples by L-clicking the print buttons on the Daily View. The examples adjust themselves for whichever fraction of an hour for which we calculate period cost: 15 min, 20 min, or 30 min.

The Daily Cost View can be included in bidding and contract documents, as described for Period Cost View and Detailed Cost View. Due to its size, it is best to include it in “Landscape” orientation, as it is done here. This is most easily done if it is a separately printed page, which is separately inserted into a printed document.

The Daily Cost View can also be inserted into a word processing file, as in this document. It is done here, in Word 97, by inserting three Section Breaks:

1. Click Insert, click Break; click Next Page in Break window, click OK, click Enter.
2. Click Insert, click Break; click Continuous in Break window, click OK, click Enter.
3. Click Insert, click Break; click Next Page in Break window, click OK.

In the first section, click File, click Page Setup. In Page Setup window click Paper Size tab, click Landscape, then click Margins tab, adjust margins, click OK. Then in the first section, we click Format, click Columns. In the Columns window, we set Number of Columns to 2, then set Spacing for Column 1 to 0, then click OK. Then go to Daily Cost View in Excel, highlight the left half (up to and including Period = 10-11), Copy and Paste into word document as described in Sec. 1.3.2.5, pg. 1-5. Click so left half will be at right margin of column. Then insert column break by click Insert, click Break, click Column Break, click OK. Then go back to Daily Cost View in Excel, highlight the right half, including one column to right of the Daily Cost View to come out even in width, and Copy and Paste in word document after the Column Break. Click so right half will be at left margin of column, next to the left half. All of this can take a little trial-and-error, including adjustments to picture size, to get it just right.

User Cost	Period Cost	Daily Cost	Project Cost

Detailed Cost View Print | Print w/ Examples

Project:	US 00 Overlay (Example)		Method:	No Publicity	
By:	R. I. Carr, 7/1/97		Traffic:	Lane Closed	
Other:	From avg traffic sheet: M1		P/U:	40%	
	Cost per Period				
Period (min):	60		15	30	45
Time of Day	Period	Sum			
12 A - 1 A	$0	$0	$0	$0	$0
1 A - 2 A	$0	$0	$0	$0	$0
2 A - 3 A	$0	$0	$0	$0	$0
3 A - 4 A	$0	$0	$0	$0	$0
4 A - 5 A	$0	$0	$0	$0	$0
5 A - 6 A	$0	$0	$0	$0	$0
6 A - 7 A	$0	$0	$0	$0	$0
7 A - 8 A	$840	$840	$210	$420	$630
8 A - 9 A	$1,800	$2,640	$450	$900	$1,350
9 A - 10 A	$1,190	$3,830	$298	$595	$893
10 A - 11 A	$930	$4,760	$233	$465	$698
11 A - 12 P	$1,150	$5,910	$288	$575	$863
12 P - 1 P	$1,520	$7,430	$380	$760	$1,140
1 P - 2 P	$1,470	$8,900	$368	$735	$1,103
2 P - 3 P	$1,490	$10,390	$373	$745	$1,118
3 P - 4 P	$1,740	$12,130	$435	$870	$1,305
4 P - 5 P	$2,360	$14,490	$590	$1,180	$1,770
5 P - 6 P	$2,770	$17,260	$693	$1,385	$2,078
6 P - 7 P	$2,020	$19,280	$505	$1,010	$1,515
7 P - 8 P	$910	$20,190	$228	$455	$683
8 P - 9 P	$580	$20,770	$145	$290	$435
9 P - 10 P	$530	$21,300	$133	$265	$398
10 P - 11 P	$290	$21,590	$73	$145	$218
11 P - 12 A	$140	$21,730	$35	$70	$105
24 hr	$21,730				

Examples

1:00P to 2:00P =	1,470	1:15P to 2:00P =	1,103
1:00P to 3:00P:		7:00A to 5:00P:	
1:00P to 2:00P =	1,470	12:00A to 5:00P =	14,490
2:00P to 3:00P =	1,490	-12:00A to 7:00A =	0
	2,960		14,490
1:15P to 2:15P:		6:45A to 5:30P:	
1:15P to 2:00P =	1,103	7:00A to 5:00P =	14,490
2:00P to 2:15P =	373	6:45A to 7:00A =	0
	1,476	5:00P to 5:30P =	1,385
			15,875

Fig. 1-21 Daily Sheet Detailed Cost View

Daily Cost View

Project:	US 00 Overlay (Example)	Method:	No Publicity
By:	R. I. Carr, 7/1/97	Traffic:	Lane Closed
Other:	From avg traffic sheet: M1	P/U:	0.4

Short Term Daily Cost Table ($)

minutes / Period	12-1A	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-1P	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	
15	0	0	0	0	0	0	0	210	450	298	233	288	380	368	373	435	590	693	505	228	145	133	73	35	15
30	0	0	0	0	0	0	0	420	900	595	465	575	760	735	745	870	1,180	1,385	1,010	455	290	265	145	70	30
45	0	0	0	0	0	0	0	630	1,350	893	698	863	1,140	1,103	1,118	1,305	1,770	2,078	1,515	683	435	398	218	105	45
60	0	0	0	0	0	0	0	840	1,800	1,190	930	1,150	1,520	1,470	1,490	1,740	2,360	2,770	2,020	910	580	530	290	140	60

User Cost | Period Cost | Detailed Cost | Project Cost | Print View | Print View with Example

Long Term Daily Cost Table (Up to 24 hr) ($)

Cost w/ Earlier Start			To	Hour-to-Hour Cost																							To
+ :15	+ :30	+ :45	From	1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12N	1P	2P	3P	4P	5P	6P	7P	8P	9P	10P	11P	12M	From
35	70	105	12M	0	0	0	0	0	0	0	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	12M
0	0	0	1A	21,730	0	0	0	0	0	0	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	1A
0	0	0	2A	21,730	21,730	0	0	0	0	0	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	2A
0	0	0	3A	21,730	21,730	21,730	0	0	0	0	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	3A
0	0	0	4A	21,730	21,730	21,730	21,730	0	0	0	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	4A
0	0	0	5A	21,730	21,730	21,730	21,730	21,730	0	0	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	5A
0	0	0	6A	21,730	21,730	21,730	21,730	21,730	21,730	0	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	6A
0	0	0	7A	21,730	21,730	21,730	21,730	21,730	21,730	21,730	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	7A
210	420	630	8A	20,890	20,890	20,890	20,890	20,890	20,890	20,890	21,730	1,800	2,990	3,920	5,070	6,590	8,060	9,550	11,290	13,650	16,420	18,440	19,350	19,930	20,460	20,750	20,890	8A
450	900	1,350	9A	19,090	19,090	19,090	19,090	19,090	19,090	19,090	19,930	21,730	1,190	2,120	3,270	4,790	6,260	7,750	9,490	11,850	14,620	16,640	17,550	18,130	18,660	18,950	19,090	9A
298	595	893	10A	17,900	17,900	17,900	17,900	17,900	17,900	17,900	18,740	20,540	21,730	930	2,080	3,600	5,070	6,560	8,300	10,660	13,430	15,450	16,360	16,940	17,470	17,760	17,900	10A
233	465	698	11A	16,970	16,970	16,970	16,970	16,970	16,970	16,970	17,810	19,610	20,800	21,730	1,150	2,670	4,140	5,630	7,370	9,730	12,500	14,520	15,430	16,010	16,540	16,830	16,970	11A
288	575	863	12N	15,820	15,820	15,820	15,820	15,820	15,820	15,820	16,660	18,460	19,650	20,580	21,730	1,520	2,990	4,480	6,220	8,580	11,350	13,370	14,280	14,860	15,390	15,680	15,820	12N
380	760	1,140	1P	14,300	14,300	14,300	14,300	14,300	14,300	14,300	15,140	16,940	18,130	19,060	20,210	21,730	1,470	2,960	4,700	7,060	9,830	11,850	12,760	13,340	13,870	14,160	14,300	1P
368	735	1,103	2P	12,830	12,830	12,830	12,830	12,830	12,830	12,830	13,670	15,470	16,660	17,590	18,740	20,260	21,730	1,490	3,230	5,590	8,360	10,380	11,290	11,870	12,400	12,690	12,830	2P
373	745	1,118	3P	11,340	11,340	11,340	11,340	11,340	11,340	11,340	12,180	13,980	15,170	16,100	17,250	18,770	20,240	21,730	1,740	4,100	6,870	8,890	9,800	10,380	10,910	11,200	11,340	3P
435	870	1,305	4P	9,600	9,600	9,600	9,600	9,600	9,600	9,600	10,440	12,240	13,430	14,360	15,510	17,030	18,500	19,990	21,730	2,360	5,130	7,150	8,060	8,640	9,170	9,460	9,600	4P
590	1,180	1,770	5P	7,240	7,240	7,240	7,240	7,240	7,240	7,240	8,080	9,880	11,070	12,000	13,150	14,670	16,140	17,630	19,370	21,730	2,770	4,790	5,700	6,280	6,810	7,100	7,240	5P
693	1,385	2,078	6P	4,470	4,470	4,470	4,470	4,470	4,470	4,470	5,310	7,110	8,300	9,230	10,380	11,900	13,370	14,860	16,600	18,960	21,730	2,020	2,930	3,510	4,040	4,330	4,470	6P
505	1,010	1,515	7P	2,450	2,450	2,450	2,450	2,450	2,450	2,450	3,290	5,090	6,280	7,210	8,360	9,880	11,350	12,840	14,580	16,940	19,710	21,730	910	1,490	2,020	2,310	2,450	7P
228	455	683	8P	1,540	1,540	1,540	1,540	1,540	1,540	1,540	2,380	4,180	5,370	6,300	7,450	8,970	10,440	11,930	13,670	16,030	18,800	20,820	21,730	580	1,110	1,400	1,540	8P
145	290	435	9P	960	960	960	960	960	960	960	1,800	3,600	4,790	5,720	6,870	8,390	9,860	11,350	13,090	15,450	18,220	20,240	21,150	21,730	530	820	960	9P
133	265	398	10P	430	430	430	430	430	430	430	1,270	3,070	4,260	5,190	6,340	7,860	9,330	10,820	12,560	14,920	17,690	19,710	20,620	21,200	21,730	290	430	10P
73	145	218	11P	140	140	140	140	140	140	140	980	2,780	3,970	4,900	6,050	7,570	9,040	10,530	12,270	14,630	17,400	19,420	20,330	20,910	21,440	21,730	140	11P
+ :15	+ :30	+ :45		1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12N	1P	2P	3P	4P	5P	6P	7P	8P	9P	10P	11P	12M	
		Cost w/	+ :15	0	0	0	0	0	0	210	450	298	233	288	380	368	373	435	590	693	505	228	145	133	73	35	0	+ :15
		Later	+ :30	0	0	0	0	0	0	420	900	595	465	575	760	735	745	870	1,180	1,385	1,010	455	290	265	145	70	0	+ :30
		Finish	+ :45	0	0	0	0	0	0	630	1,350	893	698	863	1,140	1,103	1,118	1,305	1,770	2,078	1,515	683	435	398	218	105	0	+ :45

Examples Using Short Term Daily Cost Table

1:00P to 2:00P = 1,470

1:15P to 2:00P = 1,103

1:00P to 3:00P:
1:00P to 2:00P = 1,470
2:00P to 3:00P = 1,490
2,960

1:15P to 2:15P:
1:15P to 2:00P = 1,103
2:00P to 2:15P = 373
1,476

Examples Using Long Term Daily Cost Table

1:00P to 2:00P = 1,470
7:00A to 5:00P = 14,490
1:00P to 1:00P = 21,730

1:15P to 2:15P:
1:15P to 2:00P = 1,103
2:00P to 2:15P = 373
1,475

6:45A to 5:30P:
7:00A to 5:00P = 14,490
6:45A to 7:00A = 0
5:00P to 5:30P = 1,385
15,875

Fig. 1-22 Daily Sheet Daily Cost View

From \ To	Hour-to-Hour Cost																							To / From
From	1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12N	1P	2P	3P	4P	5P	6P	7P	8P	9P	10P	11P	12M	From
12M	0	0	0	0	0	0	0	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	12M
1A	21,730	0	0	0	0	0	0	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	1A
2A	21,730	21,730	0	0	0	0	0	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	2A
3A	21,730	21,730	21,730	0	0	0	0	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	3A
4A	21,730	21,730	21,730	21,730	0	0	0	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	4A
5A	21,730	21,730	21,730	21,730	21,730	0	0	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	5A
6A	21,730	21,730	21,730	21,730	21,730	21,730	0	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	6A
7A	21,730	21,730	21,730	21,730	21,730	21,730	21,730	840	2,640	3,830	4,760	5,910	7,430	8,900	10,390	12,130	14,490	17,260	19,280	20,190	20,770	21,300	21,590	21,730	7A
8A	20,890	20,890	20,890	20,890	20,890	20,890	20,890	21,730	1,800	2,990	3,920	5,070	6,590	8,060	9,550	11,290	13,650	16,420	18,440	19,350	19,930	20,460	20,750	20,890	8A
9A	19,090	19,090	19,090	19,090	19,090	19,090	19,090	19,930	21,730	1,190	2,120	3,270	4,790	6,260	7,750	9,490	11,850	14,620	16,640	17,550	18,130	18,660	18,950	19,090	9A
10A	17,900	17,900	17,900	17,900	17,900	17,900	17,900	18,740	20,540	21,730	930	2,080	3,600	5,070	6,560	8,300	10,660	13,430	15,450	16,360	16,940	17,470	17,760	17,900	10A
11A	16,970	16,970	16,970	16,970	16,970	16,970	16,970	17,810	19,610	20,800	21,730	1,150	2,670	4,140	5,630	7,370	9,730	12,500	14,520	15,430	16,010	16,540	16,830	16,970	11A
12N	15,820	15,820	15,820	15,820	15,820	15,820	15,820	16,660	18,460	19,650	20,580	21,730	1,520	2,990	4,480	6,220	8,580	11,350	13,370	14,280	14,860	15,390	15,680	15,820	12N
1P	14,300	14,300	14,300	14,300	14,300	14,300	14,300	15,140	16,940	18,130	19,060	20,210	21,730	1,470	2,960	4,700	7,060	9,830	11,850	12,760	13,340	13,870	14,160	14,300	1P
2P	12,830	12,830	12,830	12,830	12,830	12,830	12,830	13,670	15,470	16,660	17,590	18,740	20,260	21,730	1,490	3,230	5,590	8,360	10,380	11,290	11,870	12,400	12,690	12,830	2P
3P	11,340	11,340	11,340	11,340	11,340	11,340	11,340	12,180	13,980	15,170	16,100	17,250	18,770	20,240	21,730	1,740	4,100	6,870	8,890	9,800	10,380	10,910	11,200	11,340	3P
4P	9,600	9,600	9,600	9,600	9,600	9,600	9,600	10,440	12,240	13,430	14,360	15,510	17,030	18,500	19,990	21,730	2,360	5,130	7,150	8,060	8,640	9,170	9,460	9,600	4P
5P	7,240	7,240	7,240	7,240	7,240	7,240	7,240	8,080	9,880	11,070	12,000	13,150	14,670	16,140	17,630	19,370	21,730	2,770	4,790	5,700	6,280	6,810	7,100	7,240	5P
6P	4,470	4,470	4,470	4,470	4,470	4,470	4,470	5,310	7,110	8,300	9,230	10,380	11,900	13,370	14,860	16,600	18,960	21,730	2,020	2,930	3,510	4,040	4,330	4,470	6P
7P	2,450	2,450	2,450	2,450	2,450	2,450	2,450	3,290	5,090	6,280	7,210	8,360	9,880	11,350	12,840	14,580	16,940	19,710	21,730	910	1,490	2,020	2,310	2,450	7P
8P	1,540	1,540	1,540	1,540	1,540	1,540	1,540	2,380	4,180	5,370	6,300	7,450	8,970	10,440	11,930	13,670	16,030	18,800	20,820	21,730	580	1,110	1,400	1,540	8P
9P	960	960	960	960	960	960	960	1,800	3,600	4,790	5,720	6,870	8,390	9,860	11,350	13,090	15,450	18,220	20,240	21,150	21,730	530	820	960	9P
10P	430	430	430	430	430	430	430	1,270	3,070	4,260	5,190	6,340	7,860	9,330	10,820	12,560	14,920	17,690	19,710	20,620	21,200	21,730	290	430	10P
11P	140	140	140	140	140	140	140	980	2,780	3,970	4,900	6,050	7,570	9,040	10,530	12,270	14,630	17,400	19,420	20,330	20,910	21,440	21,730	140	11P
	1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12N	1P	2P	3P	4P	5P	6P	7P	8P	9P	10P	11P	12M	

Fig. 1-23 Daily Cost View: Period Cost for Lane Closure that Starts at Time at Sides and Ends at Time at Top and Bottom

1.7.2.7 Project Cost View

1.7.2.7.1 Project Period Cost

The Project Cost View, which is also called the **Project View**, calculates each day's period cost and the total project period cost. Into the Project View we input the actual hours of lane closure for each day, and the Project View calculates the period cost for each day of the project and sums the days' period costs to calculate the period cost for the entire project. The Project View calculates total period cost using the following equation, in accord with Eq. (24),

$$\text{total period cost} = \sum_{j=1}^{M} \sum_{i=1}^{N_j} (\text{lane - closed period})_{i_j} * (\text{period cost})_{i_j} \tag{26}$$

where M = number of days of lane closure, N_j = number of lane-closed periods on j.

The Project View is useful for contractor and contract administrators to estimate contract period cost to compare alternative lane closure hours and to calculate actual contract period costs for a project. For this purpose, the Daily Cost Sheet can be an Excel file in itself, to be distributed to contractors and contract administrators for their calculations.

Fig. 1-24 is a Project View, for period costs shown in Fig. 1-19 and Fig. 1-20. Across the top are the times and period costs for one hour periods of possible lane closure. Below that is a row for each day of lane closure. For each day of lane closure, we enter the following data:

- date lane is closed, such as 6/12/98
- times of day a lane is closed, such as 7:30A-5:45P
- fraction of each hour period for which the lane is closed, such as 7A-8A = 0.5, 8A-9A = 1, 9A-10A = 1, · · · , 4P-5P = 1, 5:P-6P = 0.75.

We push F9 to calculate the output values:

- **daily lane-closed hours (hr)** = the number of hours a lane was closed each day.
- **daily period cost ($)** = total period cost for each day.
- **total periods (hr)** = total number of hours a lane was closed, during the project. For example, in Fig. 1-24, a lane was closed a total 8.25 hr between 7A and 8A, and a lane was closed a total of 110.5 hours during the project.
- **total cost ($)** = the total period costs during the project. For example, in Fig. 1-24, total period cost for lane closure = $6,930 between 7A and 8A, and total period cost for the project = $158,440.

1.7.2.7.2 Hiding and Unhiding Columns and Rows

The basic Project Cost View contains 24 hours across the top and 40 days of rows, to cover all possible lane closure hours for up to 40 days. More rows can be added for longer projects. We usually do not need to report all 24 hours for daily closures, and most projects do not take 40 days. We can reduce the size of the printed table, by "hiding" rows and/or columns that we do not need to report. Instructions for doing so are in the Project Sheet notes. Basically, to hide a set of columns (or rows), we do the following:

- L-click to highlight the headers at the top of the columns (or left end of the rows) we want to hide, such as columns BA to BG (or rows 77 to 103).

- R-click to get a menu, and L-click on Hide in the menu. The columns (or rows) disappear, and we see only the columns (or rows) to either side, such as columns BA and BH (or rows 76 and 104). We can tell what is hidden, because their sequence of alphabetic column headers (or numbered row headers) is missing the hidden column (or row) headers.

To Unhide columns (or rows), we follow similar steps:

- L-click to highlight the headers at the top of the columns to either side of the hidden columns, such as columns BA and BH (or the headers at the left end of the rows to either side of the hidden rows, such as rows 76 and 104).
- R-click to get a menu, and L-click on Unhide in the menu.

1.7.2.7.3 Daily Period Cost Calculations

The Project View calculates a day's period cost for any lane closure times. This allows us to evaluate the effect of alternative daily work hours on daily and total project period cost. Fig. 1-25 demonstrates these calculations for alternative lane closure times for "Lane Closed, No Publicity." The hourly period costs are those in the Period View of Fig. 1-19 in parallel with Fig. 1-24. We entered alternative lane closure times in each row of the Project View, as described in Sec. 1.7.2.7.1. The right-most columns tell us the daily number of hours of lane closure and user cost for each alternative. For example, we see 7A-5P period cost = $14,490, 6:45A-5:30P period cost = $15,875, and 7:45-4:30 period cost = $12,680.

Project Cost View User | Period | Detailed | Daily

Project:	US 00 Overlay (Example)	
By:	R. I. Carr, 7/1/97	
Other:	From avg traffic sheet: M1	
Method:	No Publicity	
Traffic:	Lane Closed	
P/U:	40.0%	Paste Values

		Period (1 hr)	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	Print	Daily
		Cost per Period ($/hr)	$840	$1,800	$1,190	$930	$1,150	$1,520	$1,470	$1,490	$1,740	$2,360	$2,770	Lane Closed Hours (hr)	Period Cost ($)
Day	Date	Lane Closure Times	Fraction of Hour Lane is Closed (hr)												
1	6/10/98	7A-5P	1	1	1	1	1	1	1	1	1	1		10.00	$14,490
2	6/11/98	7A-5P	1	1	1	1	1	1	1	1	1	1		10.00	$14,490
3	6/12/98	7A-4P	1	1	1	1	1	1	1	1	1			9.00	$12,130
4	6/15/98	7:30A-5:45P	0.5	1	1	1	1	1	1	1	1	1	0.75	10.25	$16,148
5	6/16/98	7A-8:15A, 11:30A-5:15P	1	0.25			0.5	1	1	1	1	1	0.25	7.00	$11,138
6	6/17/98	7A-4:30P		1	1	1	1	1	1	1	1	0.5		8.50	$12,470
7	6/22/98	10A-4:45				1	1	1	1	1	1	0.75		6.75	$10,070
8	6/23/98	7A-5P	1	1	1	1	1	1	1	1	1	1		10.00	$14,490
9	6/24/98	7A-4:45P	1	1	1	1	1	1	1	1	1	0.75		9.75	$13,900
10	6/25/98	7:15A-4:30P	0.75	1	1	1	1	1	1	1	1	0.5		9.25	$13,100
11	6/30/98	9A-3:30P			1	1	1	1	1	1	0.5			6.50	$8,620
12	7/1/98	7A-3P	1	1	1	1	1	1	1	1				8.00	$10,390
13	7/2/98	9A-2:30P			1	1	1	1	1	0.5				5.50	$7,005
Totals		Total Periods (hr)	8.25	9.25	11	12	12.5	13	13	12.5	10.5	7.5	1	110.50	$158,440
	Print	Total Cost ($)	$6,930	$16,650	$13,090	$11,160	$14,375	$19,760	$19,110	$18,625	$18,270	$17,700	$2,770	**$158,440**	

Fig. 1-24 Project Sheet Project Cost View: Total Project Period Cost

Project Cost View User | Period | Detailed | Daily

Project: US 00 Overlay (Example)
By: R. I. Carr, 7/1/97
Other: From avg traffic sheet: M1
Method: No Publicity
Traffic: Lane Closed
P/U: 40.0% Paste Values

Print

Period (1 hr)			6 A - 7 A	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	Daily	
Cost per Period ($/hr)			$0	$840	$1,800	$1,190	$930	$1,150	$1,520	$1,470	$1,490	$1,740	$2,360	$2,770	Lane Closed Hours (hr)	Period Cost ($)
Day	Date	Lane Closure Times	Fraction of Hour Lane is Closed (hr)													
1		6A-4P	1	1	1	1	1	1	1	1	1	1			10.00	$12,130
2		6:15A-4:15P	0.75	1	1	1	1	1	1	1	1	1	0.25		10.00	$12,720
3		6:30A-4:30P	0.5	1	1	1	1	1	1	1	1	1	0.5		10.00	$13,310
4		6:45A-4:45P	0.25	1	1	1	1	1	1	1	1	1	0.75		10.00	$13,900
5		6:45A-5:30P	0.25	1	1	1	1	1	1	1	1	1	1	0.5	10.75	$15,875
6		7A-5P		1	1	1	1	1	1	1	1	1	1		10.00	$14,490
7		7:15A-5:15P		0.75	1	1	1	1	1	1	1	1	1	0.25	10.00	$14,973
8		7:30A-5:30P		0.5	1	1	1	1	1	1	1	1	1	0.5	10.00	$15,455
9		7:45A-5:45P		0.25	1	1	1	1	1	1	1	1	1	0.75	10.00	$15,938
10		7:45A-4:30P		0.25	1	1	1	1	1	1	1	1	0.5		8.75	$12,680
11		7A-4P		1	1	1	1	1	1	1	1	1			9.00	$12,130
12		7A-4:30		1	1	1	1	1	1	1	1	1	0.5		9.50	$13,310
13		12P-4P							1	1	1	1			4.00	$6,220

Fig. 1-25 Project Sheet Project Cost View: Daily Period Costs of Different Lane Closures

1.7.2.8 Project Cost Considerations

This example shows a typical example of period costs for a project in which one traffic maintenance method and set of period costs were applied. In this instance, it was the Standard Method, in which there was no public information program.

Sometimes more than one set of period cost must be applied to a project. An example of this is shown in the Example Problem, in which a public information program was introduced. In that instance, there were three sets of period costs: (1) properly announced lane closures, (2) announced lane closures that were not implemented, and (3) lane closures that occurred without their being properly announced. For example, a 7A-5P lane closure was announced in advance for June 12, 1998. However, actual closure was 7:30A-5:45P. Therefore, 0.5 hr was announced but not used, 9.5 hr was announced and used, and 0.75 hr was used but not announced. Therefore, total period cost for June 12, 1988 included each of the three sets of period costs. We implemented the three sets of period costs by using three Project Sheets: one for each set of period costs. The results of the three were then summed to produce total period cost for the project.

1.8 IMPLEMENTATION GUIDELINES

1.8.1 SPECIAL PROVISIONS FOR MAINTAINING TRAFFIC

1.8.1.1 Contract Types

We implement user cost or period cost based requirements or incentives by selecting clauses and values to include in Special Provisions for Maintaining Traffic (which we call Special Provisions and contract provisions, for short). When we consider user cost or period cost, the critical contract duration is not total contract time but construction traffic maintenance time, which is usually lane-closed time. Our objective is to select a type of contract and contract provisions that deliver acceptable patterns of lane-closed time. Three common contract types provide needed flexibility: “incentive / disincentive” (I/D) contracts, “rent-a-lane” (RL) contracts, and “A and B” (A+B) contracts. These are described in subsections below, which demonstrate that the three are quantitatively equivalent. In these examples, we have limited ourselves to daily user cost, for simplicity. The Example Problem in Chapter 2 provides more detailed examples that involve hourly period costs. We can also specify liquidated damages that reimburse the public, in the form of the Department, in the event a contractor does not follow required or acceptable work patterns.

1.8.1.2 Incentive/Disincentive (I/D) Special Provisions

We must specify two items for I/D Special Provisions: (1) **contract period cost** = (estimated lane-closed days or periods) * (period cost per day or period) and (2) **I/D** = **incentive and disincentive =** period costs for all possible lane-closed periods. With I/D adjustments, the actual contract cost is

$$\begin{aligned}(\text{contract cost}) &= (\text{contract amount}) \\ &\quad + [(\text{contract period cost}) - (\text{actual period cost})]\end{aligned} \qquad (27)$$

where actual period cost is calculated from Eq. (26).

For example, for Project 1234 the Department calculates estimated contract cost = $2,000,000 and estimated lane-closed days = 20, for which estimated user cost = $120,000 / day of lane closure = 20 * 120,000 = $2,400,000. The Department selects P/U = (period cost) / (user cost) = 33.3 %, and in Special Provisions the Department specifies I/D = (33.3%) * (120,000) = $40,000 / day of reduced lane closure, and contract period cost = (lane-closed days = 20) * ($40,000 / day) = $800,000. The actual contract cost will be above or below $800,000 by the amount actual period cost is more than or less than $800,000, in accord with Eq. (26).

The Department's estimate is correct: A (fictitious) contractor, Roadway Construction, estimates its costs and determines it would bid $2,000,000 to perform Project 1234 in the normal way using one crew, with 20 days of lane closure. Roadway reviews the Special Conditions, and it estimates that using two crews can save 5 days of lane closure at an additional cost = $60,000. To earn the same profit as with one crew, Roadway's bid based on two crews is $2,000,000 + 60,000 – [(5 days) * ($40,000 / day) = $200,000] = $1,860,000. This is $140,000 less than what it would bid for one crew, so using two crews provides Roadway a much more competitive bid that contains the same profit. Therefore, Roadway decides to use two crews and perform the work in 15 days, and it submits a bid = $1,860,000.

We will assume Roadway's bid is the lowest bid, Roadway is awarded the contract and performs the work, actual land-closed time = 15 days as Roadway had estimated, actual project period cost = (lane-closed days = 15) * ($40,000 / day) = $600,000, and Roadway earns an incentive = 800,000 – 600,000 = $200,000. Roadway will receive the actual contract amount = contract cost = 1,860,000 + (800,000 – 600,000) = $2,060,000, and Roadway will receive the same profit as it would using one crew. The I/D provision has reduced user cost by (5 days) * ($120,000 / day) = $600,000, at a cost to the Department of 2,060,000– 2,000,000 = $60,000, which was Roadways incremental cost for reducing lane-closed time. Though the incentive = $40,000 / day, the actual cost of reducing user cost is ($60,000) / 5 days) = $12,000 / day which is ($12,000 / day) / ($120,000 / day) = 10% of user cost per day. Therefore, the Department selected leverage = 1 / (33.3%) = 3, but it achieved a leverage of 1 / (10%) = 10.

We can now see the importance of Guideline 7 in Sec. 1.8.2. Roadway's actions above are based on its being able to complete the project in 15 lane-closed days. Let us consider what happens if the Department interferes with Roadway realizing the five days of reduced lane closure. If the interference during construction causes Roadway to take 20 days of lane closure to complete its work using two crews, it receives contract amount = $1,860,000. Therefore, Roadway has a cost $60,000 greater than if it bid $2,000,000 and won the contract basing its bid on one crew, and it receives $140,000 less, which is a $200,000 loss relative to using one crew. The Department will have improperly saved this same $2,060,000 – $1,860,000 = $200,000 by its interference with Roadway's work, and actual user costs will be 5 * 120,000 = $600,000 more than if Roadway had been allowed to complete the work in 15 days of lane closure.

1.8.1.3 Rent-A-Lane (RL) Special Provisions

In a RL contract, the actual contract cost is adjusted by the period cost of the periods that a lane is closed (or other construction related traffic maintenance method is applied). We must specify one item for RL Special Provisions: contract period cost. With RL adjustments, the actual contract amount is

$$\begin{aligned}(\text{contract cost}) &= (\text{contract amount}) - (\text{lane rental fee}) \\ &= (\text{contract amount}) - (\text{actual period cost})\end{aligned} \qquad (28)$$

which is Eq. (27) but with contract period cost = 0.

This "zero-based budgeting" approach leads to what seem to be very large contract adjustments. Therefore, we recommend the Special Provision also include **target lane rental**, because this provides a more balanced view of lane rentals. Target lane rental is equivalent to contract period cost in the I/D provisions of Sec. 1.8.1.2. With a target lane rental,

$$(\text{lane rental fee}) = (\text{actual lane rental}) - (\text{target lane rental}) \qquad (29)$$

and actual contract cost becomes

$$(\text{contract cost}) = (\text{contract amount}) + \left[(\text{target lane rental}) - (\text{actual lane rental})\right] \qquad (30)$$

which is equivalent to Eq. (27).

Rent-a-lane or lane rental provisions parallel I/D provisions, and the calculations of Sec. 1.8.1.2 for I/D provisions are applicable to RL provisions. We will continue with the example used there, except we will substitute the RL provisions for the I/D provisions. The Department calculated estimated user cost = $120,000 / day. It selects P/U = 33.3 %, from which it specifies period cost = (33.3%) * (120,000) = $40,000 / day of lane closure. Estimated lane rental = (20 days) * ($40,000 / day) = $800,000. The Department specifies (target lane rental) = $700,000, which is somewhat lower than $800,000, as a psychological incentive to contractors.

As in Sec. 1.8.1.2, Roadway Construction can submit a bid based on using one crew taking 20 days. It's bid, for the same profit as before, would be $2,000,000 – $700,000 + [(20 days) * ($40,000 / day) = $800,000] = $2,100,000, from which it expects to earn $2,000,000 for construction. However, using 2 crews and performing the work in 15 days at an additional cost = $60,000, Roadway would bid $2,000,000 – $700,000 + $60,000 + [(15 days) * ($40,000 / day) = $600,000] = $1,960,000. This is $140,000 below its bid based on one crew, and is much more competitive, though it includes the same profit. Therefore, Roadway decides to use two crews and perform the work in 15 days, and it submits bid = $1,960,000.

We will assume Roadway's bid is the lowest bid, Roadway is awarded the contract and performs the work, actual road closed time = 15 days as Roadway had estimated, actual lane rental = actual period cost = (15 days) * ($40,000 / day) = $600,000, and by Eq. (30) Roadway receives $1,960,000 + ($700,000 – $600,000) = $2,060,000 and Roadway will receive the same profit as it would using one crew. As with the I/D example, the RL provision has reduced user cost by (5 days) * ($120,000 / day) = $600,000, at a contract cost to the Department of 2,060,000– 2,000,000 = $60,000, which was Roadways incremental cost for reducing lane-closed time. Therefore, the RL provision delivers the same performance as the I/D provision.

If the Department had used the zero-based rental approach of Eq. (28), Roadway would have bid $2,660,000, actual lane rental = (15 days) * ($40,000 / day) = $600,000, and by Eq. (28) Roadway receives $2,660,000 – $600,000 = $2,060,000 and Roadway would receive the same profit as it would using one crew. This is equivalent to the example above that has target rental cost = $700,000, except that the contract bid and original contract amount are $700,000 higher.

1.8.1.4 A Plus B (A+B) Special Provisions

The normal form of A+B contract provisions requires each contractor to bid a contract amount (*A* = bid amount) and to bid a contract duration (the bid duration). *B* = (bid duration) * (daily period cost specified by the Department), and the contractor's bid = *A* + *B*. The contractor whose bid is the lowest is awarded the contract.

Hourly lane-closed period costs are easily accommodated, by having each contractor bid both *A* = bid amount and *B* **= bid period cost.** As with the I/D and RL provisions, we must specify period cost for A+B contract provisions. *B* is based on the **period cost table** specified by the Department in the bid documents. Each contractor's **bid** = *A* + *B*, the lowest responsible bidder is awarded the contract, in which contract amount = *A*, and contract period cost = *B*. Actual contract cost is calculated at completion from Eq. (27).

A+B contract provisions parallel I/D and RL provisions, and the calculations of both Sec. 1.8.1.2 for I/D and Sec. 1.8.1.3 for RL are applicable to A+B provisions. We will continue with the example used there, except we will substitute the A+B provisions. The Department calculated estimated user cost = $120,000 / day. It selects P/U = 33.3 %, from which it specifies period cost = (33.3%) * (120,000) = $40,000 / day of lane closure. **Estimated project period cost** = (20 days) * ($40,000 / day) = $800,000.

Roadway can submit a bid based on using one crew taking 20 days. It's bid, for the same profit as before, would be *A* = $2,000,000 and *B* = (20 days) * ($40,000 / day) = $800,000, for which *A* + *B* = $2,800,000, from which it expects to earn $2,000,000 for construction. However, using 2 crews and performing the work in 15 days at an additional cost = $60,000, Roadway would bid *A* = $2,000,000 + $60,000 = $2,060,000, and *B* = (15 days) * ($40,000 / day) = $600,000, for which *A* + *B* = $2,660,000. This is $140,000 below its bid based on one crew, which is much more competitive and includes the same profit. Therefore, Roadway decides to use two crews and perform the work in 15 days, and it submits a bid of *A* = $2,060,000, *B* = $600,000, for which *A* + *B* = $2,660,000.

We will assume Roadway's bid is the lowest bid, Roadway is awarded the contract with contract amount = $2,060,000 and contract period cost = $600,000. Roadway performs the work, actual road closed time = 15 days as Roadway had estimated, actual period cost = (15 days) * ($40,000 / day) = $600,000, and by Eq. (27) Roadway receives $2,060,000 + $600,000 –

$600,000 = $2,060,000, and Roadway will receive the same profit as it would using one crew. As with the I/D and RL examples, the RL provision has reduced user cost by (5 days) * ($120,000 / day) = $600,000, at a cost to the Department of 2,060,000 – 2,000,000 = $60,000, which was Roadways incremental cost for reducing lane-closed time. Therefore, the A+B provision delivers the same performance as the I/D and RL provisions.

1.8.1.5 Liquidated Damages

A common way to enforcing traffic maintenance contract provisions is through liquidated damages in the construction contract. Liquidated damages reimburse the public (in the form of the Department) for financial damage it receives when a contractor does not fulfill contract requirements. We can use CO^3 to determine appropriate liquidated damages for traffic maintenance provisions whose purpose is to reduce user cost. When a contract requires work to be done at night, for example, liquidated damages = daytime lane closure user cost is appropriate for contract provisions that prohibit daytime lane closures.

Conversely, lane closure liquidated damages indicate the Department considers it appropriate for a contractor to close a lane if it will save the contractor more (and the Department more in the contractor's bid) than the resulting liquidated damages incurred. Therefore, contractors can consider liquidated damages to be parallel to period costs in I/D, RL, and A+B Special Provisions. We can follow that trend by calculating user cost based liquidated damages in the same manner as period costs. That is, user cost based liquidated damages = (P/U) * (user cost). The table on the left in Fig. 1-20, pg. 1-75 shows period cost expressed as liquidated damages, in a format that is suitable for Special Provisions.

1.8.2 GUIDELINES FOR IMPLEMENTATION DECISIONS

1. Our objectives are (1) that contractors perform construction work in a manner that does not cause unreasonable user costs, when balanced against project cost and other objectives, and (2) that the public only pay the contractors' incremental cost (including typical markup) for user cost savings.
2. We prefer to include all user cost related contract provisions in bidding documents, so bidders can consider the provisions in their bids. This competition provides the greatest leverage of benefit to cost.
3. Tapered user cost provisions can often balance benefit with cost, particularly when I/D contract provisions are implemented after competitive bidding or contract award.
4. User cost incentives or liquidated damages should not be so large that they cause a conflict of interest with project quality or safety.
5. We deal with user cost savings versus project cost in the same manner as other benefits versus costs. We spend public money on public benefit only when the benefit substantially exceeds the cost.
6. Similarly, we can apply time value of money and life cycle cost criteria to user costs and benefits in making project decisions. However, reduction in user cost and related increases in construction cost usually occur over the same short period of time, so we can usually neglect time value of money in selecting a method of maintaining traffic during construction.

7. The Department must administer contracts in a manner that allows contractors to fully implement user cost contract provisions and adjust their work to achieve desired user cost savings.
8. We must separate contract provisions that relate to contract duration from contract provisions that relate to lane-closures. Lane-closure provisions will often take precedence on projects that have high user costs. Early contract completion will take precedence on other projects.

With regard to Guideline 1, if user cost = $30,000 / day, we may be willing to pay up to $10,000 / day of reduction of lane-closed time. However, if it only costs a contractor an additional $4,000 / day (= incremental cost, including markup) of reduction of lane-closed time, then we would prefer paying $4,000 rather than $10,000. That is the purpose of Guideline 2: When we include user cost provisions in bidding documents, bidding competition should allow us to realize the objectives of Guideline 1. If we specify contract lane-closed days = 12 days and I/D = $10,000 / day in Special Provisions, with competitive bidding, we expect contractors will adjust their bids so the contract amount includes only their incremental costs (and associated standard markup). If it costs a contractor $4,000 / day to reduce lane-closed time, that is what the contractor will use in preparing its bid, otherwise it cannot expect to be low bidder.

Guideline 3 is particularly important when we have not followed Guideline 2, because it generally costs less per day to reduce lane-closed time the first few days than to reduce lane-closed time further. For example, on a 30 day project, it may cost a contractor very little per day to reduce lane-closed time from 30 days to 27 days, more per day to reduce it from 28 to 24, and even more to reduce it to less than 24 days. An example of a tapered provision is an incentive = $5,000 /day of reduction for up to 5 days and $10,000 /day for additional days.

Guideline 4 guards against user cost provisions overriding even more important project objectives. For example, introducing a contract period cost = $40,000 / day of lane closure into a bridge painting project that has estimated contract amount = $100,000 and estimated lane-closed days = 10 days, would overwhelm other project considerations, including quality and safety.

In establishing guidelines for setting P/U ratios, Guideline 5 indicates we should consider user benefits versus Department costs in parallel with other benefit versus cost decisions. Similarly, Guideline 6 indicates we can integrate user cost into overall project decisions. For example, we can include user cost as well as contract amount and service life in life cycle analysis of alternative highway fixes that includes the time value of money. However, once we have selected the construction or maintenance fix to use, project user cost and contract cost generally occur over the same short time period, and time value of money has no significant impact in project decisions related to contract amount and user cost such as those discussed in Sec. 1.6.

Guideline 7 emphasizes that contract administration must fully support contractors' implementation of user cost contract provisions. Contractors that work multiple crews, multiple shifts, and/or at night must be provided with proper Department support, which includes sufficient inspectors, timely inspections, and quick approvals. If a contractor wants to wait for a particularly good weather forecast to start each project segment, the Department should try to be flexible in its inspection and other support of the contractor's work.Contractors will not change their estimating, bidding, and construction methods to implement user cost provisions unless they can be sure that Department support will allow them to perform the work in the manner they have estimated and bid. The importance of Guideline 7 is demonstrated in Sec. 1.8.1.2.

Guideline 8 considers possible conflicts between lane closure duration and overall project duration. For example, a contractor may want to perform as much work without lane closure as possible, which can extend completion time. This will increase contract time but keep period costs low. We should support this, if period cost is high relative to the impact of completing the project a few days later.

CO^3 USER MANUAL

CHAPTER 2

CO^3 EXAMPLE PROJECT

2.1 INTRODUCTION

The Example Project was developed to demonstrate a typical use of CO^3 for a construction project. The project is completely fictitious, but its variables and values are representative of real projects. The Project Example is called “US 00 Overlay.” For further examples of using CO^3 go to a separate report, “CO^3 Prototypes,” which shows how CO^3 could have been used on five actual projects. For an introduction to CO^3 and instructions for its use, go to Chapter 1.

2.2 STANDARD METHOD: 7A-5P

2.2.1 INITIAL CONGESTION EVALUATION

An initial evaluation can be performed on first consideration of the project, without using a computer. The project is 6 miles of overlay on US 00, West of Maple. US 00 is 2 lanes each way. Normal capacity for its two lanes is 3400 VPH. The typical way to maintain traffic through this type of project is to close 1 lane at a time during weekdays. Traffic will pass by very close to the work, separated only by cones, and asphalt trucks will require access. This will cut capacity to significantly less than half the normal capacity.

A normal work day is 10 hours, 7:00 AM to 5:00 PM (7A-5P). We obtained the most recent weekday hourly traffic count. Fig. 2-1 shows the 24 hour traffic count for Southeast bound (SE) traffic on June 13, 1996 and for Northwest bound (NW) traffic on June 14, 1996. Peak traffic during normal work hours is 2482 VPH from 4:00 to 5:00 PM for SE traffic and 2445 VPH from 8:00 to 9:00 AM for NW traffic. Several other hours have demand that exceeds half-normal capacity. The work will probably be done in mid 1998, and demand on US 00 is rapidly expanding. Backup and related traffic delay occur anytime traffic demand exceeds capacity. All of this information indicates demand will significantly exceed capacity several hours each day under the typical method of maintaining traffic, which will cause significant backup and related traffic delays. Detailed analysis of congestion impact is warranted. We therefore will next perform more detailed analysis.

MDOT TRANSPORTATION PLANNING SERVICES DIVISION

TRAFFIC RECORD YEAR 1996

XXXX COUNTY CS NO 00000 MILE PT 06.000

STA NO 1001

ROUTE AND DESCRIPTION

US-00 100 FT S. E. OF MAPLE RD

LANES: ALL

DIRECTION:	SOUTHEAST		NORTHWEST	
DAY	THU	FRI	THU	FRI
DATE	06-15	06-16	06-15	06-16
AM				
12-0100		1835		1958
01-0200		1735		1820
02-0300		1810		1903
03-0400		2211		1722
04-0500		2482		2111
05-0600		2606		2303
06-0700		1965		1857
07-0800		1422		1335
08-0900		1238		1113
09-1000		1162		1091
10-1100		825		867
11-1200		607		570
		436		416
PM				
12-0100		252		280
01-0200	195		152	
02-0300	76		118	
03-0400	81		127	
04-0500	133		151	
05-0600	431		557	
06-0700	1280		1530	
07-0800	1681		2445	
08-0900	1401		1658	
09-1000	1473		1486	
10-1100	1697		1607	
11-1200	=======	=======	=======	=======
DAILYLY TOTAL	8448	20586	9831	19346
24 HR TOTAL	29034		29177	
AM HI HR END	12:00		12:00	
VOLUME	2606		2303	
PM HI HR END		6:00		6:00
VOLUME		1697		2445
% HI HR FACTOR				
24 HR TOTAL	9.0%		8.4%	

Fig. 2-1 Hourly Traffic Count for US 00

2.2.2 INPUT SHEET

2.2.2.1 Field Input Sheet

The Input Sheet has two basic uses: (1) It provides an easy format for handwritten specification and documentation of input values, which can be done separate from a computer. (2) It provides for computer input, calculation, and documentation of project travel data for entry into the Traffic Sheet. Fig. 2-2, which we will call "Field Input," shows the first use. It is handwritten input to the Input Sheet for US 00 Overlay, as could be done in the field or at a desk away from a computer. Recommended order for estimating input is shown in numbered circles on the left side of the sheet. Items higher than ③ are not shown, because they are normally based on travel data that are calculated by the computer.

Most of Fig. 2-2 is self-explanatory. US 00 is 2 lanes each way. The project is 6 miles of overlay, going West from Maple. The method considered here is to work in 3 segments of 2 miles for each of 4 lanes, with each segment taking 1 day, which totals = 12 segments = 12 days.

Trucks are estimated (for which we use the term “Est”) to be 10% of traffic. Normal way of maintaining traffic is to close 1 lane at a time. The general layout of the route, including the alternate route to be taken by vehicles that divert, is shown in a hand drawn map. The work zone is 2 mi, so travel distance through the work zone is 2 mi, regardless of whether a lane is closed and work is proceeding. Therefore, **work zone method travel** = **work zone normal travel** = 2 mi. The alternate route is Maple to Old 00 to Spruce, which is estimated to be 12 mi = diversion method travel distance at 50 mph = **diversion method travel speed**. Comparable distance for traffic that does not divert is **diversion normal travel distance** = 10 mi at diversion normal travel speed = 65 mph. **Normal capacity** = 3400 VPH as determined above.

The method of maintaining traffic is to close a lane, and the capacity using the method is called the “method capacity.” The method capacity for US 00 Overlay is manually calculated from MDOT “Recommended Work Zone Capacities,” shown in Fig. 2-3. For only 1 lane open where there are normally 2 lanes open, average recommended capacity = 1550 VPH. Adjusting by subtracting about 10% for working in close proximity to the work reduces estimated capacity to **method capacity** = 1400 VPH.

During construction, when the lane is closed (and capacity = 1400 VPH), proximity to work and access of asphalt trucks will reduce speed traveling through the zone, which produces speed delay. We set **threshold capacity for speed delay** = method capacity = 1400 VPH, because at that capacity the lane is closed and speed delay will occur. [It actually makes no difference to CO^3 what threshold capacity for speed delay we input for US 00 Overlay, so long as (lane-closed capacity = 1400 VPH) ≤ (threshold capacity for speed delay) < (normal capacity = 3400 VPH.] We estimate work zone speed will be 45 mph when traffic is light (when *D* » 0) and 10 mph when traffic is very heavy (when *D* ³ *C*).

Similarly, we estimate no vehicles will cancel or divert due to the project except when a lane is closed. Therefore, we set **threshold capacity for decreases to design demand** = 1400 VPH, which is a capacity when a lane is closed. [As with threshold capacity for speed delay, it makes no difference to CO^3 what threshold capacity for decreases to design demand we input for US 00 Overlay, so long as (lane-closed capacity = 1400 VPH) ≤ (threshold capacity for decreases to design demand) < (normal capacity = 3400 VPH).]

GENERAL PROJECT INPUT SHEET			
Project:			US 00 Overlay (Example Problem)
By:			R. I. Carr 10/18/96
Other:			
METHOD INPUT	METHOD #		6 mi of overlay, West from Maple. Do 3×4 lanes × 2 mi segments × 1 day US 00 is 2 lanes each way
method title			
VEHICLE INPUT	cars	trucks	
(1) raw demand (%)		10%	Est.
(0) user cost per hour ($/V hr)	$10.79	$10.79	default
(0) user cost per mile, ($/V mi)	$0.30	$1.00	default
(4) user cost per cancellation, ($/V)			
ROUTE TITLES	Standard		
DISTANCE AND SPEED INPUT	distance	speed	
(1) work zone method travel	2.0	see delay	2 mi at a time. Close 1 lane
(1) work zone normal travel	2.0	65	
(1) diversion method travel	12	50	Maple - Old 00 - Spruce = 12 mi @ 50 MPH
(1) diversion normal travel	10	65	Maple - Spruce on US 00 = 10 mi @ 65 MPH
SPEED DELAY INPUT	threshold	range	
(2) capacity for speed delay (V/hr)	1400		Est 1 lane capacity = 1400 VPH
(3) speed (when D~0) (mph)	45		Est, for low traffic
(3) speed (when D=C) (mph)	10		Est, at capacity
WORK ZONE TRAVEL	threshold	range	General Comments:
normal travel time (min)			
method travel time (when D~0) (min)			
speed delay (when D~0) (min)			
method travel time (when D=C) (min)			
speed delay (when D=C) (min)			
WORK ZONE SPEED DELAY USER COST	threshold	range	
car speed delay user cost (when D~0)			
truck speed delay user cost (when D~0)			
car speed delay user cost (when D=C)			
truck speed delay user cost (when D=C)			
DIVERSION TRAVEL			
method travel time (min)			
normal travel time (min)			
diversion delay (min)			
extra diversion travel distance (mi)			
DIVERSION USER COST	cars	trucks	
diversion delay user cost			
diversion distance user cost			
diversion user cost			
backup delay balance (min)			
DECREASE TO DEMAND	threshold	range	
(2) capacity for decreases to raw demand (V/hr)	1400		See above. Range = blank
(6) canceled cars (with no delay) (%)			
(6) canceled trucks (with no delay) (%)			
(6) canceled cars (with delay) (%/min)			
(6) canceled trucks (with delay) (%/min)			
(5) diverted cars (with no delay) (%)			
(5) diverted trucks (with no delay) (%)			
(5) diverted cars (with delay) (%/min)			
(5) diverted trucks (with delay) (%/min)			
OTHER USER COST INPUT	cars	trucks	
other user cost per vehicle ($/V)	$0.00	$0.00	default
user cost per diversion ($/V)			
CAPACITY INPUT	normal	method	
(1) total capacity each way (V/hr)	3400	1400	Est. Method = 1 lane, close to work, w/ large trucks delivering asphalt

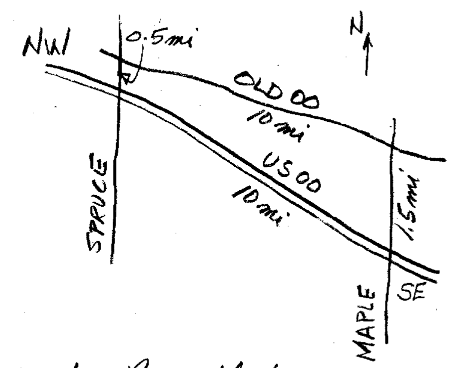

Fig. 2-2 Example Project Field Input Sheet

RECOMMENDED WORK ZONE CAPACITIES

NUMBER OF LANES		AVERAGE CAPACITY	
Normal	Open	VPH	VPHPL
3	1	1,400	1,400
2	1	1,550	1,550
5	2	3,200	1,600
4	2	3,400	1,700
3	2	3,400	1,700
4	3	5,250	1,750

ADJUSTMENTS

1. If % of heavy trucks > 10%, reduce VPH by 10%.
2. If an entrance ramp is within the closure zone, reduce freeway lane 1, VPHPL volume by the minimum of either:
   a. Ramp entering volume in VPHPL; or
   b. 800 VPHPL.
3. Add (or subtract) 10% of the VPH for above (or below) average work activities.

   Work activities which are in close proximity and/or involve larger equipment and numbers of workers would decrease capacity.

   Work activities which involve minimal noise and dust and are remote from open travel lanes would increase capacity.

GDU:BRK:mlk
01/17/95

Fig. 2-3 MDOT Recommended Work Zone Capacities

2.2.2.2 Computer Input Sheet

2.2.2.2.1 Documenting Basic Input

As mentioned above, the Input Sheet provides a useful place to document traffic input data, calculate individual vehicle travel and diversion user cost, and document estimates for the fraction of cars and trucks that cancel trips or divert to the alternate route. Therefore, we enter the information from the Field Input Sheet into the computer Input Sheet. This includes the input values we have already estimated, and our notes on why or how we selected those particular values, which we name “Input Example.” The US 00 Overlay input sheet is shown in Fig. 2-4.

#	Item			Notes
	PROJECT INPUT AND DOCUMENTATION		Project:	**US 00 Overlay (Example Problem)**
	STANDARD METHOD		By:	R. I. Carr, 10/18/96
	Copy This Sheet		Other:	
	METHOD INPUT	METHOD #		6 mi of overlay, West from Maple. Do 3 x 4 lanes x 2 mi segments x 1 day each. US 00 is 2 lanes each way.
	method title	NO PUBLICITY		Traffic count: Jun13-14, 96. Fast growing area: est traffic growth=5%. Growth = 2 yr for 1998 project.
	VEHICLE INPUT	cars	trucks	
1	design demand (%)	90.0%	10.0%	Est
0	user cost per hour ($/V hr)	$10.79	$10.79	default
0	user cost per mile, ($/V mi)	$0.30	$1.00	default
4	user cost per cancellation, ($/V)	$1.00	$2.00	About 2/3 diversion cost.
	ROUTE TITLES	Standard		
	DISTANCE AND SPEED INPUT	distance	speed	
1	work zone method travel	2.0	see delay	Close 1 lane, 2 mi at a time.
1	work zone normal travel	2.0	65	Est, from driving it.
1	diversion method travel	12.0	50	Maple - Old 00 - Spruce = 12 mi @ 50 MPH, Est from driving.
1	diversion normal travel	10.0	65	Maple to Spruce on US 00 = 10 mi @ 65 MPH. Est from driving.
	SPEED DELAY INPUT	threshold	range	
2	capacity for speed delay (V/hr)	1400		Est 1 lane capacity = 1400 VPH
3	speed (when D~0) (mph)	45		Est, for low traffic
3	speed (when D=C) (mph)	10		Est, for demand => capacity
	WORK ZONE TRAVEL	threshold	range	General Comments:
	normal travel time (min)	1.85		
	method travel time (when D~0) (min)	2.67		Demand is W of Maple, West of Maple, NW = Tu, 29 Aug 95, SE = Wed, 30 Aug 95.
	speed delay (when D~0) (min)	0.82		
	method travel time (when D=C) (min)	12.00		Info based on personal drive, Tu, 5 Dec 95, about 3 PM.
	speed delay (when D=C) (min)	10.15		
	ZONE SPEED DELAY USER COST	threshold	range	Alternate route can handle trucks, but it is a little tight. Old 00 is posted at 55 MPH. Spruce and Maple posted at 45 MPH, w/ 2-way stop signs at Old 00. Most of demand is not familiar with alternate route.
	car speed delay user cost (when D~0)	$0.15		
	truck speed delay user cost (when D~0)	$0.15		
	car speed delay user cost (when D=C)	$1.83		
	truck speed delay user cost (when D=C)	$1.83		
	DIVERSION TRAVEL			
	method travel time (min)	14.40		
	normal travel time (min)	9.23		
	diversion delay (min)	5.17		
	extra diversion travel distance (mi)	2.0		
	DIVERSION USER COST	cars	trucks	
	diversion delay user cost	$0.93	$0.93	
	diversion distance user cost	$0.60	$2.00	
	diversion user cost	$1.53	$2.93	
	backup delay balance (min)	-1.65	6.14	
	DECREASE TO DEMAND	threshold	range	
2	capacity for decreases to design demand (V/hr)	1400		Assume no decreases except when a lane is closed, when C=1400 VPH. Therefore, no range input.
6	canceled cars (with no delay) (%)	5.0%		5%: Maximum delays are large and uncertain.
6	canceled trucks (with no delay) (%)			Disregard
6	canceled cars (with delay) (%/min)	1.0%		Significant: 10% @ 10 min = 1%
6	canceled trucks (with delay) (%/min)			Disregard
5	diverted cars (with no delay) (%)	5.0%		5%: Maximum delays are large and uncertain, especially w/ backups
5	diverted trucks (with no delay) (%)			Disregard
5	diverted cars (with delay) (%/min)	1.0%		10% when demand = capacity, @ 10 MPH, w/ speed delay = 10 min, = 1% / min
5	diverted trucks (with delay) (%/min)	0.5%		Diversion is tight for trucks. Est 5% when speed delay = 10 min, = .5% / min
	OTHER USER COST INPUT	cars	trucks	
	other user cost per vehicle ($/V)	$0.00	$0.00	default
	user cost per diversion ($/V)	$1.53	$2.93	
	CAPACITY INPUT	normal	method	
1	total capacity each way (V/hr)	3400	1400	Est. Normal = typical 2 lane in one direction. Method = 1 lane, close to work, w/ large asphalt trucks: C=90%(1550)

Fig. 2-4 Example Project Computer Input Sheet

2.2.2.2.2 Calculation of Individual Vehicle Travel and User Cost Values

The computer calculates individual vehicle values for Work Zone Travel, Work Zone Speed Delay User Cost, Diversion Travel, and Diversion User Cost. These values are useful to our understanding expected project impact on traffic. They are also useful in our next step, in which we estimate the fraction of cars and trucks that will cancel trips or divert to the alternate route due to congestion at the work zone.

We can learn a lot from calculated values. **Speed delay** when traffic is light **(when $D \approx 0$)** = 0.8 min, which costs $0.15 per vehicle. Speed delay when traffic is heavy **(when $D \geq C$)** = 10.2 min, which costs $1.83. Diverting to the alternate route requires an extra 2 mi and 5.2 min over normal travel, which is $1.53 per car above normal cost and $2.93 per truck. When traffic is heavy, it is better for cars to divert than to travel through the zone, even without considering possible backup. Without considering the difficulties of traveling the more narrow alternate route, trucks are better to wait in backups up to **backup delay balance** = 6 min than to divert.

2.2.2.2.3 Estimating Canceled and Diverted Values

We are now ready to estimate the percentages of cars and trucks that will cancel their trips or divert to the alternate route. We can also briefly document our estimates on the input sheet. Our estimating is quite rough. However, it is far better than just turning our backs on the problem, which is equivalent to estimating that no vehicles cancel or divert. In particular, if no vehicles cancel or divert, all demand must pass through the zone, which would produce quite large backups. We are not sure exactly how many vehicles will cancel or divert, but we can be sure there will be a significant number if the alternative is long backups.

We will first consider the typical project, which has no particular information program to inform users on project conditions, to help them make informed travel choices, and to reduce the impact of the project on their activities. From our knowledge of the route and its normal traffic, we estimate most users do not know what alternate route(s) may be available. We can expect backups, especially if few people divert, because we know demand significantly exceeds capacity several hours each day. Heavy traffic itself produces speed delay = 10.15 min, which is a significant amount. The project is only for several days in each direction, so most users will simply come upon congested conditions without knowing alternatives to travel. Subsequently, we expect large delays that surprise users.

Engineering judgment is less important for user cost input data than traffic data, because most user cost input values are default values that result from area or system wide policy decisions. For example, user cost per vehicle hour and user cost per mile are generally default values selected by the Department to be used for all similar conditions. In this instance, **user cost per vehicle hour** = $10.79 / hr = $0.18 / min, and **user cost per mile** = $0.30 / mi for cars and $1.00 / mi for trucks. It is difficult to establish a default value for user cost per cancellation, because it is related to delay and diversion costs for vehicles that do not cancel trips, as is shown below.

Consideration of the area served indicates that normal traffic may be making trips averaging about 15 miles, which requires about 15 minutes. Adding 10 minutes for delay = $1.83 / V is a significant increase, and some trips will probably be canceled. A user cancels a trip when the cost of the trip exceeds its benefit. We can expect car and trucks to cancel when the net benefit of a trip is less than the user cost of delay. The majority of trips occur during heavy traffic, so the user cost against which to judge net benefit is user cost of delay during heavy traffic.

With significant backups occurring and little information regarding timing of lane closures, we estimate 5% of cars will cancel their trips, even if there happens to be little or no delay at the time they would travel, so **canceled cars (with no delay)** = 5%. When demand ≥ capacity, delay = 10 min even without backups, and we estimate an additional 10% of cars will cancel. This indicates **canceled cars (with delay)** = 10% / 10 min = 1 % per min of delay. We estimate trucks will not cancel, regardless of delay, so .

In this instance, the **diversion user cost** of about $1.50 per car and $2.90 per truck and the **speed delay user cost** under heavy traffic of about $1.80 per car or truck serve as a base from which to estimate user cost of cancellation. Backup delay costs an additional $0.18/min. For cars, user cost of delay = user cost of diversion ≈ $1.50 when speed delay = 10.15 – 1.65 = 8.5 min for cars. We estimate the average user cost of a canceled trip will be about half of delay costs that are avoided. Allowing for a small amount of backup, we can expect car and truck trips in heavy traffic will cancel that have net benefits that average a little more than ½of delay costs without backup. We therefore estimate **user cost of cancellation** is about 2/3 of other delay costs. This is about $1.00 for cars and $2.00 for trucks.

Again, with little information from which they can make decisions, we expect many users who know the alternative route to divert, about 5% of cars, regardless of the particular delay at their time of travel, so **diverted cars (with no delay)** = 5%. Normal traffic on the alternate route is quite light, so it can handle a large number of diversions. When demand ≥ capacity, delay = 10 min even without backups, and we estimate an additional 10% of cars will divert. This indicates **diverted cars (with delay)** = 10% / 10 min = 1 % per min of delay. Of course, if backup adds backup delay = 20 min, this would indicate 5% + 0.5% * (10 + 20) = 20% of cars will cancel and 5% + 1% * (10 + 20) = 35% will divert, leaving 45% of cars to wait through the backup to travel through the zone. Those that had the 30 min of delay would average user cost = 0.5 * ($10.79 / hr) = $5.40 per vehicle. The alternate route is somewhat tight for trucks, and we estimate few will divert when there is no delay, and 5% will divert when delay = 10 min, which is 0.5% per min of delay. Therefore, **diverted trucks (with no delay)** = 0, and **diverted trucks (with delay)** = 0.5%/min.

If we wish, we can calculate the fraction of cancellations and diversions for any particular speed and backup delay. Given that trucks = 10% of traffic, if total delay = 30 min, 45% of cars and 100% - 0.5% * (30 min) = 85% of trucks will actually travel through the zone Therefore, if delay = 30 min, cars are estimated to be 90% * 45% = 40% of original demand, and trucks are 10% * 85% = 8.5%. Therefore, actual demand = 48.5% of design demand. The actual demand will be 40% / 48.5% = 82% cars and 8.5% / 48.5% = 18% trucks.

2.2.3 ROUTE SHEET

The primary use of the Route Sheet is to show calculations for alternative routes. However, for these routes it does no more than duplicate the Travel and User Cost calculations of the Input Sheet. The Route Sheet is particularly useful for calculating the equivalent distance, time, and speed for a group of different segments that make up a route or for a group of routes that make up a set of alternate routes. This is demonstrated in Chapter 3 on Work Zone Route Calculations. The Route Sheet is not needed for this Example Project. However, the US 00 Overlay Route Sheet is shown in Fig. 2-5, to show its relationship to the Input Sheets.

ROUTE CALCULATIONS		Project:	US 00 Overlay						
		By:	R. I. Carr, 10/30/1996						
		Other:							
ROUTE USER COSTS			Copy This Sheet						
VEHICLE INPUT	cars	trucks							
user cost per hour ($/V hr)	$10.79	$10.79							
user cost per mile, ($/V mi)	$0.30	$1.00							
ROUTE TITLES		Old 00							
DISTANCE AND SPEED INPUT	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	2.0	see delay		see delay		see delay		see delay
	normal travel	2.0	65						
diversion	method travel	12.0	50						
	normal travel	10.0	65						
SPEED DELAY INPUT		threshold	range	threshold	range	threshold	range	threshold	range
capacity for speed delay (V/hr)		1400							
speed (when D~0) (mph)		45							
speed (when D=C) (mph)		10							
WORK ZONE TRAVEL									
normal travel time (min)		1.85							
method travel time (when D~0) (min)		2.67							
speed delay (when D~0) (min)		0.82							
method travel time (when D=C) (min)		12.00							
speed delay (when D=C) (min)		10.15							
WORK ZONE SPEED DELAY USER COST		threshold	range	threshold	range	threshold	range	threshold	range
car speed delay user cost (when D~0)		$0.15							
truck speed delay user cost (when D~0)		$0.15							
car speed delay user cost (when D=C)		$1.83							
truck speed delay user cost (when D=C)		$1.83							
DIVERSION TRAVEL									
diversion	method travel time (min)	14.40							
diversion	normal travel time (min)	9.23							
	diversion delay (min)	5.17							
	extra diversion travel distance (mi)	2.0							
DIVERSION USER COST		cars	trucks	cars	trucks	cars	trucks	cars	trucks
	diversion delay user cost	$0.93	$0.93						
	diversion distance user cost	$0.60	$2.00						
	diversion user cost	$1.53	$2.93						
	backup delay balance (min)	-1.65	6.14						

Fig. 2-5 Example Project Route Sheet

2.2.4 TRAFFIC SHEET

CO^3 Programs compute period and daily values of traffic and user cost variables from congestion. The Traffic Sheet is our connection to CO^3 Programs. Through the Traffic Sheet, we compute and report values for one direction of travel and one method of maintaining traffic in each computer run, which we call a CO^3 run.

- The Summary View is the input form for the CO^3 Program. Its buttons drive the CO^3 Program, and it summarizes CO^3 Program results for both directions of travel for up to four methods.
- The Overall View shows input and provides detailed output of CO^3 Program results for all variables for the latest CO^3 run. Therefore, it shows detailed information for one direction of travel using one method. It shows all information in all the views for the latest CO^3 run.
- The Traffic View parallels the Overall View for the latest CO^3 run. It shows input and provides a traffic subset of CO^3 Program results for one direction of travel using one method.

- User Cost View is like the Traffic View, except it reports a user cost subset of results.
- Combination or Combo View is like the Traffic View and User Cost view, except it reports a subset of their results.

2.2.4.1 Summary View

2.2.4.1.1 Introduction

The Summary View for four methods of US 00 Overlay is shown in Fig. 2-6. The Summary View is the heart of the Traffic Sheet, because all input to the period and daily calculations are input in the Summary View, CO^3 runs are driven by it, and results from all runs for its methods are summarized in it.

The heart of the Summary View is the input and output for each of the two directions for each of four methods, which take up most of right two-thirds of the page. The left one-third of the Summary View consists of titles and project input data that are common to all the methods and directions.

2.2.4.1.2 Input

All input data from the Input Sheet, which were shown in shaded cells, are shown as input to the Summary View, either as project input or for Method 1. Most values calculated in the Input Sheet are not shown in the Summary View. This is part of what makes the Input Sheet useful, because it provides information that would not otherwise be known.

Data are entered into the Summary View in three ways: (1) retaining default or other values already entered, (2) directly entering values, and (3) copying and pasting values from other cells. Of most concern is that the integrity of the CO^3 runs not be disturbed. Therefore, we never input anything except to the cells shown as input cells by their color. We also do not generally want to disturb formatting in cells. Also it is best to paste only the values of the data from other cells, not the cells formatting or formulas. Therefore, when we paste, we Paste Values, which is a special way of pasting. This can be done in any of three ways. First, we go to the cell in which we want to Paste Value. Then we do one of the following: (1) Use the Paste Values button on the Excel toolbar. (If it is not on the toolbar, we can add it from the Edit custom buttons.) (2) Use the Paste Special, then Paste Values. This is on the menu or you can get it by using a L-click on the mouse before pasting. (3) Use a Paste Values buttons that has been built into the Summary View.

Some input data is unique to the Traffic Sheet. **Period length** = default = 60 min for all computer runs for this Traffic Sheet. The computer will use our estimated **annual traffic growth** = 5% per year, for **years of growth** = 2 yr between the traffic count in 1996 and expected construction in 1998. We directly input these data into the Summary View.

Period Input shows 24 hours starting 12 A = default. These values are already contained in each blank Summary View. We input **historical demand** taken from the traffic counts for SE and NW directions. We do this directly the first time we use them. However, if we already had them in another Traffic Sheet, we could copy them and then Paste Value them. Design demand is calculated from historical demand, annual traffic growth, and years of growth by the Summary View as useful information and as input to CO^3 runs.

The method title and capacity data are specifically selected for each method. Method 1 is the standard method for this project, which is to close one lane from 7:00 AM to 5:00 PM each work day. As selected on the Input Sheet, **capacity** = 3400 VPH under normal conditions when both lanes are open, and **capacity** = 1400 VPH when one lane is closed. Therefore, we directly input or copy these capacity data for the appropriate hours.

2.2.4.1.3 CO^3 Computer Run and Summary Output

We can do a CO^3 run for each direction and method for which we have input data. We do this clicking on the Calculate button in the column for the particular direction and method we wish to run. Fig. 2-6 shows the Summary Output results for both directions of Method 1, for the input data we have discussed. These results are for each day for which the input data are applicable. In this case, the data are for each day the lane is closed 7A-5P.

Total user cost = $35,433 for each day a SE lane is closed and $37,919 for each day a NW lane is closed. For the 6 days each direction we estimate the highway will be closed, we can manually calculate **project user cost** = 6 * (35,433 + 37,919 = 73,352) = $440,112. About 80% of this is from delay, and about 20% is from canceled and diverted traffic. **Maximum backup** is 347 vehicles for SE bound traffic and 264 vehicles for NW traffic, and **maximum backup length is** 2 and 1.5 mi respectively. **Average delay** is about 6 min per vehicle. User cost for all vehicles (average **user cost / design demand** ≈ $1.15) is about the same as delay cost for those that travel through the zone (average **delay cost / actual demand** ≈ $1.10). With car **user cost per diversion** = $1.53 > average user cost, we do not want to divert all traffic. However, a publicity program that informs users might increase cancellations and diversions, and their attendant cost, but it might also significantly decrease delay as congestion is decreased.

Validity of output = VALID for both directions on the bottom line of Summary Output, which indicates that when the report was printed, the output was valid for the input data shown. [A value (validity of output) = INVALID indicates the output shown is based on input values of which at least one has changed. This "validity check" guards against some input data having become changed, between the last CO^3 run and printing of the Summary View.] The status of the validity check is shown by the following:

- **Auto** = ON indicates the validity checker was on for all methods during the last CO^3 run.
- **Print** = ON indicates the validity checker was on and was run when this view was printed.
- **Now** = OK indicates the validity checker was run at or since the last CO^3 run. It means nothing when Auto = ON. However, if Auto = OFF, then Now = OK would indicate a validity check had been run since the last CO^3 run.

2.2.4.2 Overall View

The Overall View shows output for all output variables for every period for the latest CO^3 run. Therefore, it provides detailed output that supports the Summary Output that is shown in the Summary View. The Overall View is actually the transition between the Summary View and the CO^3 Program. CO^3 copies the input data for the appropriate method and direction into the Overall View. The CO^3 Program then reads the direction and method input values from the Overall View, computes values of all traffic variables for each period, and outputs the results to the Overall View. The Overall View then calculates and shows user cost for each period and appropriate maximum, minimum, and average or total values for all output variables. It also shows the same

Summary Output as the Summary View. Therefore, the Overall View shows all input, detailed output, and summary output for the latest CO^3 run.

The Traffic View, User Cost View, and Combined View each contain a subset of the Overall View output data. Their purpose is to provide a format that is a little larger and more concise, which can be particularly useful for presentations to an audience or to concentrate attention on only a few related variables.

The Overall View for 7A-5P, SE direction is shown in Fig. 2-7. This shows that **backup** occurred 12P to 1P and 2P to 4P, peaking at 4P. **Maximum delay** = 23.53 min for a vehicle that arrived between 4P and 5P. A large number of cars canceled or diverted throughout the work period, with **maximum decrease to cars** = 1,151 cars of the **design demand** = 2,736 that arrived 4P-5P. Hourly **user cost** varied from $1,723 at 7A-8A to $6,685 at 4P-5P, except for $1,040 for vehicles that arrived 5P-6P after both lanes were open but were delayed because of the backup remaining at 5P.

2.2.4.3 Traffic, User Cost, and Combined Views

The Traffic View, User Cost View, and Combined View of the Traffic Sheet for US 00 Overlay, with a lane closed for work 7A-5P, SE direction, are shown in Chapter 1, in Fig. 1-11, Fig. 1-12, and Fig. 1-13. (In this Chapter, Fig. 2-13 is one of several Combined Views, and Fig. 2-36 is a User Cost View.) As described above, these show a subset of period output for traffic variables, user cost variables, and a more reduced subset of both traffic and user cost variables, that are internally copied from the Overall View. They also each show all the input values and Summary Output that are also shown in the Summary View and Overall View. These views together provide no more information that is not contained in the Overall View, but in three times as many pages, which requires three times as much printing. It is also generally easier to understand detailed output when it is all together, as in the Overall View. Therefore, we generally only print, review, and keep the Overall Views, together with the Summary View.

2.2.5 IMPACT SHEET

2.2.5.1 Introduction

The Impact Sheet, also called the Impact Summary Sheet, shows daily user cost, total user cost, construction cost, and total project cost including user cost for different methods of maintaining traffic. Its purpose is to show in one place a summary of traffic, user cost, and construction cost so we can understand the overall impact of each method of maintaining traffic. Fig. 2-8 shows the US 00 Overlay Impact Sheet computer screen. The shaded upper portion is for input of values from the Output Summary of the Summary View of the Traffic Sheet and from the Summary portion of the Construction Sheet. This portion is not normally printed. The lower portion is the part that is normally printed as a report. Much of the data it shows is not shown anywhere else.

SummaryView

Copy This Sheet	period length (min)	60
	annual traffic growth (%)	5.00%
Update	years of growth	2

VEHICLE INPUT	cars	trucks
design demand (%)	90.0%	10.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION	
PROJECT TITLE	US 00 Overlay Example Problem
Paste Values C.S.	90000
JOB #	00000
START DATE	6/00/98

REPORT INFORMATION	
REPORT TITLE	DETAILED USER COST REPORT SUMMARY VIEW
DIVISION	
REPORT BY	R. I. Carr
REPORT DATE	1/2/97

NOTES:

METHOD INPUT	METHOD 1		METHOD 2		METHOD 3		METHOD 4	
method title	7A-5P		7A-5P, Publicity		7A-3P, Publicity		Night, 8P-6A	
DISTANCE AND SPEED (mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone — method travel	2.0	see delay	2.0	see delay	2.0	see delay	2.0	see delay
work zone — normal travel	2.0	65	2.0	65	2.0	65	2.0	65
diversion — method travel	12.0	50	12.0	50	12.0	50	12.0	50
diversion — normal travel	10.0	65	10.0	65	10.0	65	10.0	65
SPEED DELAY	threshold	range	threshold	range	threshold	range	threshold	range
capacity for speed delay (V/period)	1400		1400		1400		1400	
speed (when D~0) (mph)	45		45		45		45	
speed (when D=C) (mph)	10		10		10		10	
DECREASE TO DEMAND	threshold	range	threshold	range	threshold	range	threshold	range
capacity for decreases to design demand (V/period)	1400		1400		1400		1400	
canceled cars (with no delay) (%)	5.0%							
canceled trucks (with no delay) (%)								
canceled cars (with delay) (%/min)	1.0%		3.0%		3.0%		1.0%	
canceled trucks (with delay) (%/min)			1.0%		1.0%			
diverted cars (with no delay) (%)	5.0%							
diverted trucks (with no delay) (%)								
diverted cars (with delay) (%/min)	1.0%		3.0%		3.0%		1.0%	
diverted trucks (with delay) (%/min)	0.5%		1.0%		1.0%		0.5%	
OTHER USER COST INPUT Update	cars	trucks	cars	trucks	cars	trucks	cars	trucks
other user cost per actual demand ($/V)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
user cost per diversion ($/V)	$1.53	$2.93	$1.53	$2.93	$1.53	$2.93	$1.53	$2.93
Paste Values	Calculate	Calculate	Calculate	Calculate	Calculate	Calculate	Calculate	Calculate

Summary | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

PERIOD INPUT			backup at start (V)		0	0	0	0	0	0	0	0
direction	SE	NW	SE	NW	SE	NW	SE	NW	SE	NW	SE	NW
period	historical demand		design demand		capacity		capacity		capacity		capacity	
(hr)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)
12 A	436	416	481	459	3400	3400	3400	3400	3400	3400	1400	1400
1 A	252	280	278	309	3400	3400	3400	3400	3400	3400	1400	1400
2 A	195	152	215	168	3400	3400	3400	3400	3400	3400	1400	1400
3 A	76	118	84	130	3400	3400	3400	3400	3400	3400	1400	1400
4 A	81	127	89	140	3400	3400	3400	3400	3400	3400	1400	1400
5 A	133	151	147	166	3400	3400	3400	3400	3400	3400	1400	1400
6 A	431	557	475	614	3400	3400	3400	3400	3400	3400	3400	3400
7 A	1280	1530	1411	1687	1400	1400	1400	1400	1400	1400	3400	3400
8 A	1681	2445	1853	2696	1400	1400	1400	1400	1400	1400	3400	3400
9 A	1401	1658	1545	1828	1400	1400	1400	1400	1400	1400	3400	3400
10 A	1473	1486	1624	1638	1400	1400	1400	1400	1400	1400	3400	3400
11 A	1697	1607	1871	1772	1400	1400	1400	1400	1400	1400	3400	3400
12 P	1835	1958	2023	2159	1400	1400	1400	1400	1400	1400	3400	3400
1 P	1735	1820	1913	2007	1400	1400	1400	1400	1400	1400	3400	3400
2 P	1810	1903	1996	2098	1400	1400	1400	1400	1400	1400	3400	3400
3 P	2211	1722	2438	1899	1400	1400	1400	1400	3400	3400	3400	3400
4 P	2482	2111	2736	2327	1400	1400	1400	1400	3400	3400	3400	3400
5 P	2606	2303	2873	2539	3400	3400	3400	3400	3400	3400	3400	3400
6 P	1965	1857	2166	2047	3400	3400	3400	3400	3400	3400	3400	3400
7 P	1422	1335	1568	1472	3400	3400	3400	3400	3400	3400	3400	3400
8 P	1238	1113	1365	1227	3400	3400	3400	3400	3400	3400	1400	1400
9 P	1162	1091	1281	1203	3400	3400	3400	3400	3400	3400	1400	1400
10 P	825	867	910	956	3400	3400	3400	3400	3400	3400	1400	1400
11 P	607	570	669	628	3400	3400	3400	3400	3400	3400	1400	1400
Total	29034	29177	32010	32168	61600	61600	61600	61600	65600	65600	61600	61600

SUMMARY OUTPUT — traffic method	7A-5P		7A-5P, Publicity		7A-3P, publicity		night, 8P-6A	
direction	SE	NW	SE	NW	SE	NW	SE	NW
total user cost	$35,433	$37,919	$25,250	$26,599	$17,712	$20,876	$4,818	$4,275
user cost of delays	$27,903	$29,737	$14,828	$15,560	$10,680	$12,241	$4,183	$3,720
user cost of decreases	$7,530	$8,183	$10,421	$11,039	$7,032	$8,635	$634	$556
maximum backup (V)	347	264	0	0	0	0	0	0
maximum backup length (lane mi)	2.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
maximum delay (min.)	23.5	21.5	9.3	9.2	7.5	9.2	7.4	6.4
average delay (min)	5.9	6.4	3.4	3.6	2.2	2.7	0.7	0.7
total delay, except diversions (V hr)	2586	2756	1374	1442	990	1134	388	345
total vehicles canceled(V)	2850	3094	3985	4221	2689	3302	236	207
total vehicles diverted (V)	2960	3216	3985	4221	2689	3302	249	218
total decrease in demand (V)	5809	6310	7970	8442	5378	6604	484	424
% decrease in demand	18.1%	19.6%	24.9%	26.2%	16.8%	20.5%	1.5%	1.3%
delay per diverted vehicle (min)	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
total diversion delay (V hr)	255	277	343	364	232	284	21	19
average delay, including diversions (min)	5.8	6.3	3.7	3.9	2.5	2.9	0.8	0.7
total delay, including diversions (V hr)	2841	3033	1718	1806	1221	1419	409	363
user cost / design demand ($/V)	$1.11	$1.18	$0.79	$0.83	$0.55	$0.65	$0.15	$0.13
delay cost / actual demand ($/V)	$1.06	$1.15	$0.62	$0.66	$0.40	$0.48	$0.13	$0.12
Auto: ON Print: ON Now: OK — validity of output	VALID	VALID	VALID	VALID	VALID	VALID	VALID	VALID

copy these values into Impact Sheet

Fig. 2-6 Summary View of Traffic Sheet

Overall View

period length (min)	60	
annual traffic growth (%)	5.00%	
years of growth	2	
VEHICLE INPUT	**cars**	**trucks**
design demand (%)	90.0%	10.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION	
PROJECT TITLE	US 00 Overlay Example Problem
C.S.	90000
JOB #	00000
START DATE	6/00/98

REPORT INFORMATION	
REPORT TITLE	DETAILED USER COST REPORT OVERALL SHEET
DIVISION	
REPORT BY	R. I. Carr
REPORT DATE	1/2/97

NOTES:

METHOD INPUT		METHOD 1	
method title		7A-5P	
DISTANCE AND SPEED	(mi) (mph)	distance	speed
work zone	method travel	2.0	see delay
	normal travel	2.0	65.0
diversion	method travel	12.0	50.0
	normal travel	10.0	65
SPEED DELAY		threshold	range
capacity for speed delay (V/period)		1400	
speed (when D~0) (mph)		45	
speed (when D=C) (mph)		10	
DECREASE TO DEMAND		threshold	range
capacity for decreases to design demand (V/period)		1400	
canceled cars (with no delay) (%)		5.0%	
canceled trucks (with no delay) (%)			
canceled cars (with delay) (%/min)		1.0%	
canceled trucks (with delay) (%/min)			
diverted cars (with no delay) (%)		5.0%	
diverted trucks (with no delay) (%)			
diverted cars (with delay) (%/min)		1.0%	
diverted trucks (with delay) (%/min)		0.5%	
OTHER USER COST INPUT		cars	trucks
other user cost per vehicle ($/V)		$0.00	$0.00
user cost per diversion ($/V)		$1.53	$2.93

SUMMARY OUTPUT	
traffic method	7A-5P
direction	SE
total user cost	$35,433
user cost of delays	$27,903
user cost of decreases	$7,530
maximum backup (V)	347
maximum backup length (lane mi)	2.0
maximum delay (min.)	23.5
average delay (min)	5.9
total delay, except diversions (V hr)	2,586
total vehicles canceled(V)	2,850
total vehicles diverted (V)	2,960
total decrease in demand (V)	5,809
% decrease in demand	18.1%
delay per diverted vehicle (min)	5.2
total diversion delay (V hr)	255
average delay, including diversions (min)	5.8
total delay, including diversions (V hr)	2,841
user cost / design demand	$1.11
delay cost / actual demand	$1.06

Overall | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

direction: SE | backup at start (V): 0

period (hr)	capacity (V/period)	hist. demand (V/period)	design demand (V/period)	actual demand (V/period)	backup eop (V)	backup length eop (lane.mile)	maximum delay (min)	total period delay (Vhr)	average backup delay (min)	average speed delay (min)	average delay (min)		user cost / total vehicles ($/V)	delay cost / actual demand ($/V)
12 A	3400	436	481	481	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
1 A	3400	252	278	278	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
2 A	3400	195	215	215	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
3 A	3400	76	84	84	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
4 A	3400	81	89	89	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
5 A	3400	133	147	147	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
6 A	3400	431	475	475	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
7 A	1400	1280	1411	1,110	0	0.00	6.68	124	0.00	6.68	6.68		$1.22	$1.20
8 A	1400	1681	1853	1,356	0	0.00	9.63	218	0.00	9.63	9.63		$1.61	$1.73
9 A	1400	1401	1545	1,190	0	0.00	7.56	150	0.00	7.56	7.56		$1.34	$1.36
10 A	1400	1473	1624	1,235	0	0.00	8.08	166	0.00	8.08	8.08		$1.42	$1.45
11 A	1400	1697	1871	1,366	0	0.00	9.74	222	0.00	9.74	9.74		$1.63	$1.75
12 P	1400	1835	2023	1,436	36	0.20	11.51	259	0.68	10.15	10.83		$1.76	$1.95
1 P	1400	1735	1913	1,362	0	0.00	11.68	243	0.64	10.07	10.71		$1.74	$1.93
2 P	1400	1810	1996	1,424	24	0.14	11.07	252	0.46	10.15	10.61		$1.73	$1.91
3 P	1400	2211	2438	1,563	187	1.06	17.89	379	4.38	10.15	14.54		$2.14	$2.61
4 P	1400	2482	2736	1,560	347	1.97	23.53	478	10.49	7.89	18.38		$2.44	$3.30
5 P	3400	2606	2873	2,873	0	0.00	6.12	96	2.01	0.00	2.01		$0.36	$0.36
6 P	3400	1965	2166	2,166	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
7 P	3400	1422	1568	1,568	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
8 P	3400	1238	1365	1,365	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
9 P	3400	1162	1281	1,281	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
10 P	3400	825	910	910	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
11 P	3400	607	669	669	0	0.00	0.00	0	0.00	0.00	0.00		$0.00	$0.00
TOT	61,600	29,034	32,010	26,201				2,586				AVG	$1.11	$1.06
MAX	3400	2606	2873	2873	347	1.97	23.53	478	10.49	10.15	18.38	MAX	$2.44	$3.30
MIN	1400	76	84	84	0	0.00	0.00	0	0	0.00	0.00	MIN	$0.00	$0.00

Overall | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

period (hr)	canceled cars (V)	canceled trucks (V)	diverted cars (V)	diverted trucks (V)	decrease to cars (V/period)	decrease to trucks (V/period)	total period decrease (V/period)	decrease cost cars ($)	decrease cost trucks ($)	delay cost cars ($)	delay cost trucks ($)	decrease cost ($)	delay cost ($)	user cost ($)
12 A	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
1 A	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
2 A	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
3 A	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
4 A	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
5 A	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
6 A	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
7 A	148	0	148	5	297	5	301	$375	$14	$1,170	$164	$389	$1,334	$1,723
8 A	244	0	244	9	488	9	497	$617	$26	$2,043	$305	$643	$2,348	$2,992
9 A	175	0	175	6	349	6	355	$442	$17	$1,415	$202	$459	$1,617	$2,076
10 A	191	0	191	7	382	7	389	$484	$19	$1,569	$227	$503	$1,795	$2,298
11 A	248	0	248	9	496	9	505	$628	$27	$2,079	$312	$654	$2,391	$3,045
12 P	288	0	288	11	577	11	588	$729	$32	$2,424	$373	$761	$2,797	$3,558
1 P	270	0	270	10	541	10	551	$684	$30	$2,274	$349	$714	$2,623	$3,337
2 P	280	0	280	11	561	11	571	$709	$31	$2,357	$361	$740	$2,718	$3,458
3 P	429	0	429	18	857	18	875	$1,084	$52	$3,494	$591	$1,136	$4,085	$5,221
4 P	576	0	576	25	1,151	25	1,176	$1,456	$74	$4,334	$821	$1,530	$5,155	$6,685
5 P	0	0	0	0	0	0	0	$0	$0	$936	$104	$0	$1,040	$1,040
6 P	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
7 P	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
8 P	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
9 P	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
10 P	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
11 P	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0
TOT	2,850	0	2,850	110	5,699	110	5,809	$7,209	$322	$24,095	$3,808	$7,530	$27,903	$35,433
MAX	576	0	576	25	1,151	25	1,176	$1,456	$74	$4,334	$821	$1,530	$5,155	$6,685
MIN	0	0	0	0	0	0	0	$0	$0	$0	$0	$0	$0	$0

Fig. 2-7 Overall View for 7A-5P, SE Direction

2.2.5.2 Input to Impact Sheet

2.2.5.2.1 Traffic and User Cost Input

Fig. 2-8 shows the complete Impact Sheet for all four methods in the Fig. 2-6 Summary View, including the Traffic Summary Input and Construction Summary Input that is not normally printed. All we have discussed at this point is the Summary Output data from Summary View for 7A-5P. We have input this in the manner described in Chapter 1. In addition, we have input **% closed** = 0.5 for both SE and NW, which directs the Impact Sheet to calculate daily traffic and user cost values based on the average of the two directions, SE and NW. This is because only one lane is closed at a time, and half the days have SE impacts and half have NW impacts. From this 7A-5P input data, the Impact Sheet has calculated daily traffic user cost output, which is shown in the first unshaded area.

2.2.5.2.2 Construction Cost Input

Considerations of construction variables at this point have been limited to the following:

- Estimated contract cost = $500,000
- Lane-closed hours per day = 10
- Estimated duration = 12 lane-closed days.

These are all we need as input to calculate the other traffic, user cost, and total project cost values. We have no need for the Construction Sheet at this point, because its only use is to estimate construction costs for methods other than that we normally use to perform the work. Labor cost is the only construction cost input we have not discussed, but it is unimportant in itself. It is included in Fig. 2-8, because the figure shows all values for all methods, including those we have not yet addressed.

2.2.5.2.3 Impact Sheet Results

The Impact Sheet calculates Total User Cost, and Total Project Cost, which is the sum of Total User Cost and Construction Cost. From this we see that total user cost = $440,114, which is almost as much as Construction Cost. Obviously, user cost is quite large, and we need to consider alternative methods to see if we can decrease user cost without unreasonable increases in construction cost.

2.2.6 RESULTS FOR THE STANDARD METHOD: 7A-5P

We now see that for the standard method of performing the work, which we call 7A-5P in the Example Project, there are two primary sets of results: (1) Summary Output in the Summary View and (2) Summary of Impacts in the Impact Sheet. More detailed results are reported in the Overall View for each direction. These data are supported by values in the Field Input Sheet (Fig. 2-2) and Computer Input Sheet (Fig. 2-4).

2.3 ALTERNATIVE METHODS

2.3.1 METHOD 2 - ALTERNATIVE 1 : 7A-5P, PUBLICITY

2.3.1.1 Introduction

Review of the Standard Method shows large backups and delays, **total user cost** = \$440,114, of which **delay costs** = \$345,836 ≈ 80%. As mentioned earlier, we expect users will be uninformed unless there is significant public information that prepares users for the project. This will include a custom sign, map, business information, and media program to tell users at what times a lane will be closed in each direction, at what time major delays will occur, and alternate routes users can use to avoid delays.

2.3.1.2 Input Sheet

A well informed public will know when significant delays can be expected and the alternate route that will avoid delays. Compared to the Standard Method, we expect more users will cancel and divert when they know delays will be large and fewer will cancel and divert when there are no significant delays. Fig. 2-9 is the Input Sheet for a good public information program. It differs from Fig. 2-4 in the values and comments for decrease to demand variables, which are the only variables that should be impacted. The changes are documented in the figure.

We can be somewhat technical in our estimates. From the Input Sheet, Fig. 2-9, we see that **car diversion user cost** = \$1.53, **backup delay balance** = – 1.65 min, and **speed delay (when *D*=*C*)** = 10.15 min. Therefore, car speed delay user cost = car diversion user cost = \$1.53 when speed delay = [speed delay (when D=C) = 10.15 min] + [backup delay balance = – 1.65 min] = 8.5 min. This indicates that if drivers have complete knowledge and they are governed only by user cost, cars are indifferent when speed delay = 8.5 min between (1) traveling through the work zone and (2) diverting to the alternate route, both of which have user cost = \$1.53.

For US 00 Overlay, with a good public information program, when delay = 8.5 min, we estimate 25% of cars will cancel or move their trip to a time with less demand, and 40% of the remaining 75% of cars = 30% will divert when car speed delay = 8.5 min. This becomes **canceled cars (with delay)** = (25%) / (8.5 min) ≈ 3% / min, and **diverted cars (with delay)** = (30%) / (8.5 min) ≈ 3% / min. Trucks have a different balance point at which truck delay user cost = truck diversion user cost = \$2.93. This balance occurs when backup delay = truck backup delay balance = 6.14 min, at which point truck delay = 10.15 + 6.14 = 16.29 min. Considering the alternate route is tight for trucks, when delay = 16 min, we estimate 20% of trucks will cancel or move to another time and 20% of trucks will divert, from which we calculate **canceled trucks (with delay)** =**diverted trucks (with delay)** = (20%) / (16 min) ≈ 1% / min. We will disregard any cancellations and diversions when there is no delay, because (1) with good public information we expect decreases (without delay) will be small, and (2) decreases (with delay) will be mush larger than decreases (without delay), given there are delays of several minutes. For example, with diverted cars (with delay) = 3%/min, if diverted cars (without delay) = 1%, then 5 min of delay creates diverted cars = 5 * (3%/min) + 1% = 15% + 1% = 16%, of which diverted cars (without delay) is only a small part.

IMPACT SUMMARY SHEET

SUMMARY SHEET INPUT	Project:	US 00 Overlay (Example Problem)
	By:	R. I. Carr 12/31/96
Copy This Sheet	Other:	

Paste Values

PASTE VALUES only from Summary View of Traffic Sheet. Use DELETE to undo.

TRAFFIC SUMMARY INPUT — % closed	50%	50%	50%	50%	50%	50%	50%	50%
traffic method	7A-5P		7A-5P, Publicity		7A-3P, Publicity		Night, 8P-6A	
direction	SE	NW	SE	NW	SE	NW	SE	NW
total user cost ($)	$35,433	$37,919	$25,250	$26,599	$17,712	$20,876	$4,818	$4,275
user cost of delays ($)	$27,903	$29,737	$14,828	$15,560	$10,680	$12,241	$4,183	$3,720
user cost of decreases ($)	$7,530	$8,183	$10,421	$11,039	$7,032	$8,635	$634	$556
maximum backup (V)	347	264	347	0	0	0	0	0
maximum backup length (lane mi)	2.0	1.5	2.0	0.0	0.0	0.0	0.0	0.0
maximum delay (min.)	23.5	21.5	23.5	9.2	7.5	9.2	7.4	6.4
average delay (min)	5.9	6.4	5.9	3.6	2.2	2.7	0.7	0.7
total delay, except diversions (V hr)	2586	2756	2586	1442	990	1134	388	345
total vehicles canceled (V)	2850	3094	2850	4221	2689	3302	236	207
total vehicles diverted (V)	2960	3216	2960	4221	2689	3302	249	218
total decrease in demand (V)	5809	6310	5809	8442	5378	6604	484	424
% decrease in demand	18.1%	19.6%	24.9%	26.2%	16.8%	20.5%	1.5%	1.3%
delay per diverted vehicle (min)	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
total diversion delay (V hr)	255	277	255	364	232	284	21	19
average delay, including diversions (min)	5.8	6.3	6.3	3.9	2.5	2.9	0.8	0.7
total delay, including diversions (V hr)	2841	3033	2841	1806	1221	1419	409	363
user cost / design demand ($/V)	$1.11	$1.18	$0.79	$0.83	$0.55	$0.65	$0.15	$0.13
delay cost / actual demand ($/V)	$1.06	$1.15	$0.62	$0.66	$0.40	$0.48	$0.13	$0.12

Paste Values

PASTE VALUES only from Construction Sheet. Use DELETE to undo.

CONSTRUCTION SUMMARY INPUT	10 hr day shift		10 hr day shift, with publicity		8 hr day shift, with publicity		10 hr night shift	
lane-closed hours per day (hr/day)	10		10		8		10	
lane-closed days (day)	12.0		12.0		15.4		12.6	
labor cost ($)	$150,000		$150,000		$154,286		$157,895	
project cost ($)	$500,000		$516,000		$522,000		$532,923	

Copy This Sheet

Print Summary of Impacts for 4 Methods, Vertical

SUMMARY OF IMPACTS		US 00 Overlay (Example Problem)
	By:	R. I. Carr 12/31/96
	Other:	Do not change or copy in summaries below this area

USER COST, DAILY — traffic method	7A-5P	7A-5P, Publicity	7A-3P, Publicity	Night, 8P-6A
total user cost, daily ($)	$36,676	$25,924	$19,294	$4,547
user cost of delays, daily ($)	$28,820	$15,194	$11,460	$3,952
user cost of decreases , daily ($)	$7,857	$10,730	$7,834	$595
total delay, except diversions, daily (V hr)	2,671	2,014	1,062	366
total vehicles canceled, daily (V)	2,972	3,535	2,995	221
total vehicles diverted, daily (V)	3,088	3,590	2,995	233
total decrease in demand, daily (V)	6,059	7,125	5,991	454
total diversion delay, daily (V hr)	266	309	258	20
total delay, including diversions, daily (V hr)	2,937	2,323	1,320	386
USER COST, TOTAL				
total user cost ($)	$440,114	$311,091	$297,681	$57,432
user cost of delays ($)	$345,836	$182,330	$176,819	$49,914
user cost of decreases ($)	$94,278	$128,761	$120,863	$7,518
maximum backup (V)	347	347	0	0
maximum backup length (lane mi)	2.0	2.0	0.0	0.0
maximum delay (min.)	23.5	23.5	9.2	7.4
average delay (min)	6.2	4.8	2.4	0.7
total delay, except diversions (V hr)	3,192	3,712	3,981	254
total vehicles canceled (V)	35,662	42,423	46,213	2,792
total vehicles diverted (V)	37,051	43,082	46,213	2,947
total decrease in demand (V)	72,713	85,505	92,427	5,740
% decrease in demand	18.9%	25.6%	18.7%	1.4%
average delay per diverted vehicle (min)	5.2	5.2	5.2	5.2
total diversion delay (V hr)	3,192	3,712	3,981	254
average delay, including diversions (min)	6.1	5.1	2.7	0.7
total delay, including diversions (V hr)	35,244	27,880	20,369	4,880
average user cost / design demand ($/V)	$1.14	$0.81	$0.60	$0.14
average delay cost / actual demand ($/V)	$1.11	$0.64	$0.44	$0.12
CONSTRUCTION COST — method	10 hr day shift	10 hr day shift, with publicity	8 hr day shift, with publicity	10 hr night shift
lane-closed hours per day (hr/day)	10	10	8	10
lane-closed days (day)	12.0	12.0	15.4	12.6
labor cost ($)	$150,000	$150,000	$154,286	$157,895
project cost ($)	$500,000	$516,000	$522,000	$532,923
TOTAL PROJECT COST	$940,114	$827,091	$819,681	$590,355

Do not change these areas or copy into these areas.

Fig. 2-8 Example Project Impact Sheet (including input area)

2.3.1.3 Traffic Sheet

We input Method 2 values to the Summary View in the Traffic Sheet. These values are shown in Fig. 2-6. We call Method 2 "7A-5P, Publicity", to distinguish it from Method 1. The only inputs that differ from 7A-5P are the decrease to demand values described immediately above and shown in the comments portion of Fig. 2-9. Therefore, we copy all input values from the Input Sheet, Fig. 2-9 to Summary View Method 2 in the same way we did from Fig. 2-6 to Summary View Method 1. Alternatively, we could copy only the decrease to demand values from the Input Sheet, Fig. 2-9 to Summary View Method 2 and copy all other values from Summary View Method 1 input values to Summary View Method 2.

After we input all variables, on the Summary View we hit Calculate for Method 2 SE. CO^3 computes and shows Method 2 SE period values in all views except the Summary View and shows Summary Output in all views. We then hit Calculate for Method 2 NW. CO^3 erases all Method 2 SE values in all views except Summary View, and it computes and shows Method 2 NW period values in all views except the Summary View and shows Summary Output in all views. The Summary Output is captured in the Summary View, Fig. 2-6. We have not printed the other views, which would show period output.

Most important, we see that publicity has significantly reduced total user cost in each direction. The number of vehicles that have canceled and diverted has increased and user cost of decreases has increased, but knowledgeable cancellations and diversions have reduced actual demand during times of greatest potential delay. This has cut user cost of delays almost in half compared to 7A-5P, which had no significant publicity. With a good publicity program, we see that expected backups have been reduced to zero, and average delay has been reduced almost 40%, from 6.0 sec to 3.7 sec.

2.3.1.4 Impact Sheet

2.3.1.4.1 User Costs

We now enter the 7A-5P, Publicity method's Summary Output values in the Impact Sheet to calculate and show daily and total traffic and user cost values, as shown in Fig. 2-8 Example Project Impact Sheet (including input area). The public information program does not change project duration, so we enter the same values for **lane-closed days** = 12 days. From this, the Impact Sheet calculates total user cost. The information program saves about $130,000 in user cost, it eliminates all backups, and it reduces total delay by 20%, from 35,000 to 28,000 V hr.

2.3.1.4.2 Construction and Total Project Cost

Implementing a public information program for US 00 Overlay does not change lane-closed hours per day, or construction cost. We estimate the public information program will cost roughly $10,000 in fixed cost plus $500 per day, for a total increase in project cost of 10,000 + 12 * (500) = $16,000 for the 12 days of lane closure. Therefore, estimated **project cost** = 500,000 + 16,000 = $516,000. We enter this into the Impact Sheet to calculate **total project cost** = $827,000. From this we see a savings in user cost of about $130,000 when $16,000 is spent on a good public information program. However, we still estimate **user cost** = $311,000. This indicates we should identify and consider additional alternatives.

PROJECT INPUT AND DOCUMENTATION	Project:		US 00 Overlay (Example Problem)
WITH PUBLICITY	By:		R. I. Carr, 10/18/96
Copy This Sheet	Other:		
METHOD INPUT	METHOD 2		6 mi of overlay, West from Maple. Do 3 x 4 lanes x 2 mi segments x 1 day each. US 00 is 2 lanes each way.
method title	WITH PUBLICITY		Traffic count: Jun13-14, 96. Fast growing area: est traffic growth=5%. Growth = 2 yr for 1998 project.
VEHICLE INPUT	cars	trucks	
(1) design demand (%)	90.0%	10.0%	Est
(0) user cost per hour ($/V hr)	$10.79	$10.79	default
(0) user cost per mile, ($/V mi)	$0.30	$1.00	default
(4) user cost per cancellation, ($/V)	$1.00	$2.00	About 2/3 diversion cost.
ROUTE TITLES	Standard		
DISTANCE AND SPEED INPUT	distance	speed	
(1) work zone method travel	2.0	see delay	Close 1 lane, 2 mi at a time.
(1) work zone normal travel	2.0	65	Est, from driving it.
(1) diversion method travel	12.0	50	Maple - Old 00 - Spruce = 12 mi @ 50 MPH, Est from driving.
(1) diversion normal travel	10.0	65	Maple to Spruce on US 00 = 10 mi @ 65 MPH. Est from driving.
SPEED DELAY INPUT	threshold	range	
(2) capacity for speed delay (V/hr)	1400		Est 1 lane capacity = 1400 VPH
(3) speed (when D~0) (mph)	45		Est, for low traffic
(3) speed (when D=C) (mph)	10		Est, for demand => capacity
WORK ZONE TRAVEL	threshold	range	General Comments:
normal travel time (min)	1.85		
method travel time (when D~0) (min)	2.67		Demand is W of Maple, West of Maple, NW = Tu, 29 Aug 95, SE = Wed, 30 Aug 95.
speed delay (when D~0) (min)	0.82		
method travel time (when D=C) (min)	12.00		Info based on personal drive, Tu, 5 Dec 95, about 3 PM.
speed delay (when D=C) (min)	10.15		
ZONE SPEED DELAY USER COST	threshold	range	Alternate route can handle trucks, but it is a little tight. Old 00 is posted at 55 MPH. Spruce and Maple posted at 45 MPH, w/ 2-way stop signs at Old 00. Most of demand is not familiar with alternate route.
car speed delay user cost (when D~0)	$0.15		
uck speed delay user cost (when D~0)	$0.15		
car speed delay user cost (when D=C)	$1.83		
uck speed delay user cost (when D=C)	$1.83		
DIVERSION TRAVEL			
method travel time (min)	14.40		
normal travel time (min)	9.23		
diversion delay (min)	5.17		
extra diversion travel distance (mi)	2.0		
DIVERSION USER COST	cars	trucks	
diversion delay user cost	$0.93	$0.93	
diversion distance user cost	$0.60	$2.00	
diversion user cost	$1.53	$2.93	
backup delay balance (min)	-1.65	6.14	
DECREASE TO DEMAND	threshold	range	
(2) capacity for decreases to design demand (V/hr)	1400		Assume no decreases except when a lane is closed, when C=1400 VPH. Therefore, no range input.
(6) canceled cars (with no delay) (%)			Blank, because of good publicity
(6) canceled trucks (with no delay) (%)			Blank, because of good publicity
(6) canceled cars (with delay) (%/min)	3.0%		Est 25% @ (10.15 - 1.65 min) ~ 3%/min
(6) canceled trucks (with delay) (%/min)	1.0%		Est 20% @ (10.15 + 6.14) ~ 1%/min
(5) diverted cars (with no delay) (%)			Blank, because of good publicity
(5) diverted trucks (with no delay) (%)			Blank, because of good publicity
(5) diverted cars (with delay) (%/min)	3.0%		Est [40% * (1 - 25%) = 30%] @ (10.15 - 1.65 = 8.5 min) ~ 3%/min
(5) diverted trucks (with delay) (%/min)	1.0%		Diversion is tight for trucks. Est 20% @ (10.15 + 6.14) ~ 1%/min
OTHER USER COST INPUT	cars	trucks	
other user cost per vehicle ($/V)	$0.00	$0.00	default
user cost per diversion ($/V)	$1.53	$2.93	
CAPACITY INPUT	normal	method	
(1) total capacity each way (V/hr)	3400	1400	Est. Normal = typical 2 lane in one direction.Method = 1 lane, close to work, w/ large asphalt trucks: C=90%(1550)

Fig. 2-9 Example Project Input Sheet for Decrease to Demand, with Publicity

2.3.2 METHOD 3 - ALTERNATIVE 2 : 7A-3P, PUBLICITY

2.3.2.1 Introduction and Input Sheet

Inspection of the Summary View shows design demand from 3P-5P NW and from 4P-5P SE are larger than average, and their user cost values are also larger than average. We will therefore calculate impacts for reducing the work day to lane-closed hours per day = 8 hr by reopening the lane at 3:00 PM instead of 5:00 PM. We will use the same public information program used in 7A-5P, Publicity. Therefore the “WITH PUBLICITY” Input Sheet in Fig. 2-9 applies to this alternative, and all traffic input values are the same, except capacity = 3400 VPH from 3P-5P. We call this alternative “7A-3P, Publicity” to reflect the 7A to 3P lane closure.

2.3.2.2 Traffic Sheet

We add Method 3 values to the Summary View in the Traffic Sheet. This consists of copying and pasting all input values from Method 2, using Paste Values. We enter the method title and change to capacity = 3400 for 3A and 4A. We push Calculate for each direction, and CO^3 computes all output values, which are summarized in 7A-3P, Publicity Summary Output. This indicates that total user cost has decreased by about $7,000 each day. We do not know whether there is a net benefit, until we consider construction cost impact of changing the work day.

2.3.2.3 Construction Cost Sheet

2.3.2.3.1 Introduction

At this point, we need to estimate **construction cost** for working eight hours per day instead of the more typical 10 hours per day. “7A-3P, Publicity” is the first alternative for which we need the Construction Sheet to estimate construction cost impacts, because changing the lane-closed hours changes the work hours, which changes construction costs. Fig. 2-10 shows a completed Construction Cost Sheet that includes the appropriate alternative: “8 hr day shift, with publicity.”

The purpose of the Construction Sheet is to estimate and document project cost for alternative ways of maintaining traffic and changes in construction they require, based on the project cost of the Standard Case. We do this by first estimating the contract cost and lane-closed days for the Standard Case. We then estimate the portions of the total Standard Case cost that will be affected by changes in the alternatives and pertinent values for those portions. Then we input corresponding values for each alternative. The Construction Sheet then calculates the estimated lane-closed days and project cost for each alternative.

The Construction Sheet is not used to calculate the impacts for the standard method of performing the work. And we can calculate the total project cost for some alternatives without using the Construction Sheet. For example, we calculated the construction cost impact for the publicity program in Sec. 2.3.1.4.2, pg. 2-18 without using the Construction Sheet, because publicity did not impact normal construction costs. However, we have shown this as Alternative 1, “10 hr day shift, with publicity”, in Fig. 2-10 to demonstrate how the project cost for “7A-5P, Publicity” can be calculated on the Construction Sheet.

2.3.2.3.2 Standard Case

We must first enter information for the Standard Case, because that provides the base for estimating the cost of performing the work in an alternative manner. We name the Standard Case “10 hr day shift”, which describes the construction context. In that left side input column, we enter the first three input values: Estimated **contract cost** = $500,000, **lane-closed days** = 12, and **lane-closed hours per day** = 10, which we discussed in Sec. 2.2.5.2.2, pg. 2-15. We continue entering values for input variables, and we document each in the right column (shown in parentheses below). For example, we see contract cost was estimated in the normal way (Est. normal way), and lane-closed days was calculated from 4 lanes of 6 miles in 2 mile segments (Est: 4 lanes x 6 mi @ 2 mi per day = 12 days). **Lane-closed days per work day** = 1.00 (default. W/ daily closure, no reason to work weekends, etc). **Relative productivity** = 1 (default). The documentation leaves an informal record by which we can trace our decisions and sources.

We have estimated **labor cost %** = 30%, because the work is not labor intensive, but labor probably costs more than equipment (Not labor intensive. Labor > equip. Material is large). We estimate daily lane closure and reopening takes one hour each work day (Est lane closure + lane opening = 1 hr per day) for this project, so **productive hours per shift** = lane-closed hours per day – 1 = 9 hr. The labor cost for closing and opening lanes, which is often included in the “traffic maintenance” contract pay item, is included in the contractor’s labor cost. The Construction Sheet calculates **labor cost** = $150,000. This is not important in itself; it is used only as a base for estimating cost differences for other alternatives.

We estimate **equipment cost %** = 20%, from which **equipment cost, relative** = $100,000. We do not expect other costs to vary significantly enough from one alternative to another to break them down. [Note: All significant work is expected to be done while lane is closed. Therefore, our estimates of labor cost % and equipment cost % infer that material cost plus other contract cost = 50%. Material cost is not input, because its cost is not significantly impacted by changes in traffic maintenance.]

2.3.2.3.3 Alternative 2: 8 hr day shift, with publicity

The most notable difference between this alternative and the Standard Case is that work will only be performed eight hours each work day, and **lane-closed hours per day** = 8 hr. We also input our estimated cost for the public information program. These, and other important differences among alternatives are marked with an ellipse, ⬭, to indicate their importance.

Calculations show working fewer hours each day has increased **work days** from 12 to 15.4 days and **total paid hours** from 120 to 123.4 hr, producing estimated **labor cost difference** = $4,286. That, plus the cost of publicity = **agency total cost** = $17,714, increases **contract cost** by $4,286 and **project cost** by $22,000. This alternative has therefore added additional cost for 3.4 hr for 3.4 days of lane closure plus cost of publicity to the Standard Case.

2.3.2.4 Impact Sheet

The Impact Sheet shows “7A-3P, Publicity” reduces **total user cost** by 311,000 – 292,000 = $19,000 and reduces **average delay** by 3.8 - 2.7 = 1.1 sec, but it increases **project cost** by $6,000. The net impact is to decrease **total project cost** by $16,000. This is a small and not particularly significant improvement. We would like to do better.

2.3.3 METHOD 4 - ALTERNATIVE 3 : NIGHT, 8P-6A

2.3.3.1 Introduction

Methods 1, 2, and 3 have high user costs, and there are no apparent variations in the timing of daytime lane closures that will reduce them significantly. Therefore, we will calculate impacts of closing lanes and performing work at night, when demand is low.

2.3.3.2 Summary View

We expect work will be performed 10 hours per night, during lane closure. Design demand < capacity = 1400 VPH in both directions from 8P to 7A. We select 8P to 6A as the lane-closed period for our calculations, and we name this method "Night, 8P-6A" to represent its primary characteristics.

There is no need for a public information program, if user cost is low. With low delay, we disregard canceled and diverted vehicles (with no delay). We estimate canceled and diverted vehicles with delay) are the same as in Method 1, with no publicity. We could show this on an Input Sheet, but there is no real need to do so. Therefore, we Copy and Paste Value the Method Input values from Method 1, except for canceled and diverted vehicles (with no delay). We input capacity = 1400 for the 10 periods titled 8P to 5A and capacity = 3400 for 6A to 7P. [Note: If there is an end of period backup for 11P (midnight), a different Traffic Sheet must be used that ends at a period that has no end of period backup.]

We click the Calculation button for Method 4, SE and then for Method 4, NW and CO^3 computes the Summary Output values shown for Method 4 in the Summary View, Fig. 2-6. This shows daily total user cost is reduced to less than $5,000 in each direction, which is only about 20% of the 10 hour day shift, with publicity.

2.3.3.3 Construction Sheet

Night work differs significantly form day work. We estimate **relative productivity** = 0.95 (cxcept night est = 0.95), due to working off-hours, with less light. which is a significant reduction. It could be as low as 0.90. We estimate **equipment cost/hr/item, relative** = $500 for lighting and related items (Est lighting and other nighttime related small equipment items). We estimate material cost is about 30%, which will increase 2%, which adds 2% * 30% * $500,000 = $3,000 (Est 2% x (material = 30%) x $500,000 = $3,000). We estimate project overhead and markup = 20% of contract cost and this will increase about 10% for nighttime work, a total increase of **other % cost** = 2% (Misc 10% x (20% cost) for night). Construction Sheet calculations show **project cost** = $532,923, an increase of $32,923 above the Standard Case. **Lane-closed days** increased 0.6 days to 12.6 days, because of reduced productivity.

CONSTRUCTION COST SHEET		Project: US 00 Overlay (Example Problem)			
		By: R. I. Carr 10/18/96		important	
		Other:			
CONSTRUCTION COST	Standard Case	Alternative 1	Alternative 2	Alternative 3	
Copy This Sheet General Input method	10 hr day shift	10 hr day shift, with publicity	8 hr day shift, with publicity	10 hr night shift	Std = 10 hr day. Add publicity, at some cost, but to reduce user cost. 8 hr day shift tries to avoid rush hours. Night avoids most traffic.
contract cost ($)	$500,000	NA	NA	NA	Est, normal way
lane closed days (day)	12	NA	NA	NA	Est: 4 lanes x 6 mi @ 2 mi per day = 12 days
lane closed days per work day	1.00	1.00	1.00	1.00	default. W/ daily closure, no reason to work weekends, etc
lane closed hours per day (hr/day)	10	10	8	10	Lane is closed while work is done.
relative productivity	1	1	1	0.95	default, except night est = 0.95
Labor Cost					
labor cost %	30%	NA	NA	NA	Not labor intensive. Labor > equip. Material is large.
fixed mobilization (standard crew hr)	0.00	0.00	0.00	0.00	default. No labor cost for mobilization w/ lane open.
shifts per day	1.00	1.00	1.00	1.00	default
crews per shift	1.00	1.00	1.00	1.00	default
workers per crew (relative)	1.00	1.00	1.00	1.00	default
productive hours per shift	9.00	9.00	7.00	9.00	Est lane closure + lane opening = 1 hr per day
paid hours per shift	10.00	10.00	8.00	10.00	default = same as lane closed hr
% premium time	0%	0%	0%	0%	default
premium cost ($PT/$ST)	1.40	1.40	1.40	1.40	default
workers (relative)	1.0	1.0	1.0	1.0	
work days	12.0	12.0	15.4	12.6	
lane closed days (day)	12.0	12.0	15.4	12.6	
productive hours, total	108.0	108.0	108.0	113.7	
worker production hours, total (relative)	108.0	108.0	108.0	113.7	
paid hours, total (relative)	120.0	120.0	123.4	126.3	
cost per paid hour (relative)	1.00	1.00	1.00	1.00	
labor cost index	1.00	1.00	1.03	1.05	
labor cost ($)	$150,000	$150,000	$154,286	$157,895	
labor cost difference ($)	na	$0	$4,286	$7,895	
Equipment Cost- Relative Based					
equipment cost %	20%	NA	NA	NA	Equip significant, < labor or material.
relative number of items	1.0	1.0	1.0	1.0	default
equipment fixed cost/item, relative					
equipment fixed cost, relative ($)	$0	$0	$0	$0	
equipment cost/day/item, relative					
equipment cost ($) (day based)*	$0	$0	$0	$0	
equipment cost/hr/item, relative	1.0	1.0	1.0	1.0	default
equipment cost ($) (hr based)*	$100,000	$100,000	$100,000	$105,263	
equipment cost, relative ($)	$100,000	$100,000	$100,000	$105,263	
equipment cost difference, relative ($)	na	$0	$0	$5,263	
Equipment Cost - Total Based					
relative number of items				1.0	
equipment fixed cost/item, total					
equipment fixed cost, total ($)	$0	$0	$0	$0	
equipment cost/day/item, total				$500	Est lighting and other nighttime related small equipment items.
equipment cost, total ($) (day based)*	0	0	0	$6,316	
equipment cost/hr/item, total					
equipment cost,total ($) (hr based)*	0	0	0	0	
equipment cost,total ($)	$0	$0	$0	$6,316	
equipment cost difference, total ($)	na	$0	$0	$6,316	
Material Cost					
material cost ($)				$3,000	Est 2% x (material = 30%) x $500,000 = $3,000
materal cost difference ($)	na	$0	$0	$3,000	
Traffic Maintenance Cost					
traffic maintenance fixed cost ($)					
traffic maintenance daily cost ($/day)					
traffic maintenance hourly cost ($/hr)					
traffic maintenance total cost ($)	$0	$0	$0	$0	
traffic maintenance cost difference ($)	na	$0	$0	$0	
Other Contract Cost				nighttime	
other % cost (%)				2.00%	Misc 10% x (20% cost) for night
other fixed cost ($)					
other daily cost ($/day)					
other hourly cost ($/hr)					
other total cost ($)	$0	$0	$0	$10,449	
other total cost difference ($)	na	$0	$0	$10,449	
Agency Cost		publicity	publicity		
agency % cost (%)					
agency fixed cost ($)		$10,000	$10,000		Est: publicity cost has first cost plus daily cost
agency daily cost ($/day)		$500	$500		
agency hourly cost ($/hr)					
agency total cost ($)	$0	$16,000	$17,714	$0	
agency cost difference ($)	na	$16,000	$17,714	$0	
Total Construction Cost					
contract cost ($)	$500,000	$500,000	$504,286	$532,923	
contract cost difference ($)	na	$0	$4,286	$32,923	
project cost ($)	$500,000	$516,000	$522,000	$532,923	
project cost difference ($)	na	$16,000	$22,000	$32,923	
Summary method	10 hr day shift	10 hr day shift, with publicity	8 hr day shift, with publicity	10 hr night shift	
lane closed hours per day (hr/day)	10	10	8	10	
lane closed days (day)	12.0	12.0	15.4	12.6	
labor cost ($)	$150,000	$150,000	$154,286	$157,895	
project cost ($)	$500,000	$516,000	$522,000	$532,923	

*Generally do not use both hr based and day based equip cost.

You can copy these values into Impact Sheet.

Fig. 2-10 Example Project Construction Cost Sheet

2.3.3.4 Impact Sheet

Into the Impact Sheet we have input Summary Output from Summary View and Summary from Construction Sheet, as shown in Fig. 2-6. Impact Sheet calculations show nighttime construction **total user cost** = $57,000, a reduction of $383,000 below 7A–5P and $220,000 below 7A–3P, Publicity. **Maximum delay** = 7.4 min, **average delay** = 0.7 min, **% decrease in demand** = 1.4%, and **total delay** = 5,000 V hr. These are still significant, and we wish we could easily decrease them further, but they are acceptable.

We can achieve these reductions in traffic and user cost impacts at an increase in estimated construction cost of $33,000 if we perform construction at night. Nighttime construction will have other negative project impacts, including disturbing nighttime rest of neighboring residents. With construction completing almost 2 mi per night, residents will be disturbed only two nights, one for each direction of overlay. And they will not be disturbed or delayed by daytime construction congestion that would accompany daytime work. Overall, the benefit of nighttime construction significantly exceeds the cost to the degree such that nighttime construction is warranted if it is otherwise practical. Certainly, this example project analysis indicates the project should be planned for nighttime construction.

We can also explicitly consider "disturbance" costs for neighboring residents in our user cost analysis. Example: We estimate there are 100 residences per two mile segment of work and we estimate disturbance cost = $20/residence/night. Therefore, **disturbance cost** = 100 * 20 = $2,000/night. **Total disturbance cost =** (2,000/night) * (12.6 nights) = $25,200. Including disturbance cost in project cost produces **total project cost** = 590,355 + 25,200 = $615,555.

2.3.4 ADDITIONAL ALTERNATIVES

This example has demonstrated three common types of alternatives. Other alternatives are briefly described below.

2.3.4.1 Different Size Crew(s)

The Standard Case estimates contract cost for the lowest bidding contractor, which will be based on the most competitive crew size and equipment. We estimate that paving equipment productivity and asphalt delivery are the elements that determine the rate of placing asphalt. Increasing the crew size will increase hourly cost with little impact on hourly production and lane-closed days.

2.3.4.2 Starting Work Earlier

Starting work before 7A will increase the fraction of work performed during off-peak demand, and it will decrease traffic and user cost impact below working peak hours. Nighttime construction is the most complete implementation of this strategy, and it produces the least congestion. We will not consider other alternatives for starting work earlier here if night work is acceptable. If night work is not acceptable, we then look for a more acceptable way to avoid peak hours. This includes starting work earlier and working the standard 10 hr shift or paying overtime to work longer shifts.

2.3.4.3 Multiple Crews

Two or more crews working simultaneously on the same lane would complete the work in fewer lane-closed days. We estimate this is not practical for this project, because it would be difficult to coordinate multiple crews, perhaps of multiple contractors, including doubling or tripling the frequency of asphalt truck deliveries.

2.3.5 SENSITIVITY ANALYSIS

Sensitivity analysis is calculation of differences in output that result from differences in input. We use sensitivity analysis to help us apply engineering judgment to CO^3 results and related project decisions. In formal sensitivity analysis, we input different values of input variables into our calculations to determine the impact that changes in input have on output and decisions. Fig. 2-11 is a Summary View that shows several examples that we compare to Method 1 and Method 2 in Fig. 2-6. Input values in Fig. 2-11 that differ from Fig. 2-6 are marked with an ellipse, such as capacity = 1500 or canceled cars (with no delay) = 2.0%.

Method 1 and Method 2 in Fig. 2-11 are the same as Method 1 and Method 2 in Fig. 2-6, except we have increased our estimate of capacity from 1400 VPH to 1500 VPH ≈ 7%, to determine the impact of a higher estimate of capacity on 7A-5P lane closures. We see in summary output that the increase in estimated capacity results in total user cost without publicity decreasing \$35,433 – \$32,724 = \$2,709 for SE and \$37,919 – \$34,553 = \$3,366 for NW, which are decreases of about 9%. With a publicity program, total user cost decreases \$25,250 – \$24,425 = \$825 for SE and \$26,599 – \$25,731 = \$868 for NW, which are decreases of about 3%. From this sensitivity analysis, we see that user cost is sensitive to capacity. However, we do not expect that possible inaccuracy in our estimate of capacity will substantially change our project cost estimates or our major project decisions.

Method 3 in Fig. 2-11 is the same as Method 1 in Fig. 2-6, except we have input canceled cars (with no delay) = diverted cars (with no delay) = 2% instead of 5%, to determine the impact of a lower estimate of decrease in cars (with no delay) when lane closures are not announced. We find that the lower estimates for decrease in cars result in total user cost increasing \$40,793 – \$35,433 ≈ 15% for SE bound traffic and \$43,511 – \$37,919 ≈ 15% for NW bound traffic.

Method 4 in Fig. 2-11 is the same as Method 2 in Fig. 2-6, except we have input canceled cars (with delay) = diverted cars (with delay) = 2%/min instead of 3%/min, to determine impact of a lower estimate of decrease in cars (with delay) when lane closures are announced. This shows the impact of a less effective publicity program. We find the lower estimates for decrease in cars results in total user cost increasing \$29,307 – \$25,250 = \$4,057 ≈ 16% for SE bound traffic and \$30,993 – \$26,599 = \$4,394 ≈ 17% for NW bound traffic. We also see backup in both directions, which we do not have with the higher decreased cars (with delay). The changes in input in Method 3 and Method 4 shows us that user cost is sensitive to our estimates of decreases in traffic, but possible inaccuracies in our estimates should not substantially change our project cost estimates or our major project decisions. The sensitivity of user cost to traffic decreases (with delay) in Method 4 reinforces the need for publicity to guide users to alternate routes to avoid backup and resulting delays.

2.4 PROJECT IMPLEMENTATION

2.4.1 INTRODUCTION

2.4.1.1 Construction Project Implementation

Construction project implementation decisions differ from decisions related to project scope. In addressing project scope, we are primarily interested in selecting a practical method for performing the work and producing realistic contract cost and user cost estimates. This provides for practical and realistic decisions throughout the long life of project realization, from concept to completion. Therefore, on project scope decisions for US 00 Overlay, we first determined that traffic impact and user cost were significant. Then we determined that nighttime work was most practical from a contract cost and user cost perspective. If nighttime work is not practical, for other reasons, we determined the work should be performed during daytime, accompanied by an appropriate public information program that eliminates backups. Therefore, the project scope would select either nighttime work or daytime work with publicity, and CO^3 provides realistic estimates of user cost and contract cost for whichever of the two methods are selected. These estimates are shown in the Impact Sheet described in Sec. 2.2.5 and shown in Fig. 2-8.

Implementation decisions are generally more detailed, because they determine the specific charges to be included in construction contract Special Provisions for Maintaining Traffic (which we call Special Provisions, for short) for individual time periods for which the lane will be closed. Period cost is our name for the specific charges that are included in construction contract Special Provisions. The Impact Sheet provides for our project scope needs and for our decisions during implementation on whether to specify period cost in contract Special Provisions. However, the Impact Sheet and Traffic Sheet that we use for scope decisions usually does not provide the information we need to calculate period costs.

2.4.1.2 Average Traffic

For most construction projects in which both directions of traffic are approximately equal in hourly traffic demand and construction work, we can specify the same traffic maintenance methods and period costs for both directions. For such balanced projects, we can input average traffic demand for the two directions to calculate user cost and period cost. If hourly traffic demands in both directions are about equal, but there is an imbalance in construction work and therefore duration of lane closure between the two directions, the average traffic demand can be weighted accordingly. The general formula for average value of a variable, *x*, for directions *a* and *b*, accommodates such an imbalance:

$$(\text{average value of } x) = (\%\text{ closed})_a * x_a + (\%\text{ closed})_b * x_b \tag{31}$$

SummaryView

Copy This Sheet	period length (min)	60
	annual traffic growth (%)	5.00%
Update	years of growth	2
VEHICLE INPUT	cars	trucks
design demand (%)	90.0%	10.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION			
PROJECT TITLE	US 00 Overlay Example Problem		
Paste Values	C.S.	90000	
	JOB #	00000	
	START DATE	6/00/98	

REPORT INFORMATION		
REPORT TITLE	DETAILED USER COST REPORT SUMMARY VIEW	
	DIVISION	
	REPORT BY	R. I. Carr
	REPORT DATE	1/2/97

NOTES:

METHOD INPUT	METHOD 1		METHOD 2		METHOD 3		METHOD 4	
method title	7A-5P, No Publicity capacity=1500		7A-5P, Publicity capacity=1500		7A-5P, No Publicity lower decrease		7A-5P, Publicity lower decrease	
DISTANCE AND SPEED (mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone: method travel	2.0	see delay	2.0	see delay	2.0	see delay	2.0	see delay
work zone: normal travel	2.0	65	2.0	65	2.0	65	2.0	65
diversion: method travel	12.0	50	12.0	50	12.0	50	12.0	50
diversion: normal travel	10.0	65	10.0	65	10.0	65	10.0	65
SPEED DELAY	threshold	range	threshold	range	threshold	range	threshold	range
capacity for speed delay (V/period)	1500		1500		1400		1400	
speed (when D~0) (mph)	45		45		45		45	
speed (when D=C) (mph)	10		10		10		10	
DECREASE TO DEMAND	threshold	range	threshold	range	threshold	range	threshold	range
capacity for decreases to design demand (V/period)	1500		1500		1400		1400	
canceled cars (with no delay) (%)	5.0%				2.0%			
canceled trucks (with no delay) (%)								
canceled cars (with delay) (%/min)	1.0%		3.0%		1.0%		2.0%	
canceled trucks (with delay) (%/min)			1.0%				1.0%	
diverted cars (with no delay) (%)	5.0%				2.0%			
diverted trucks (with no delay) (%)								
diverted cars (with delay) (%/min)	1.0%		3.0%		1.0%		2.0%	
diverted trucks (with delay) (%/min)	0.5%		1.0%		0.5%		1.0%	
OTHER USER COST INPUT (Update)	cars	trucks	cars	trucks	cars	trucks	cars	trucks
other user cost per actual demand ($/V)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
user cost per diversion ($/V)	$1.53	$2.93	$1.53	$2.93	$1.53	$2.93	$1.53	$2.93
Paste Values	Calculate	Calculate	Calculate	Calculate	Calculate	Calculate	Calculate	Calculate

Summary | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

PERIOD INPUT			backup at start (V)		0	0	0	0	0	0	0	0
direction	SE	NW	SE	NW	SE	NW	SE	NW	SE	NW	SE	NW
period	historical demand		design demand		capacity		capacity		capacity		capacity	
(hr)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)
12 A	436	416	481	459	3400	3400	3400	3400	3400	3400	3400	3400
1 A	252	280	278	309	3400	3400	3400	3400	3400	3400	3400	3400
2 A	195	152	215	168	3400	3400	3400	3400	3400	3400	3400	3400
3 A	76	118	84	130	3400	3400	3400	3400	3400	3400	3400	3400
4 A	81	127	89	140	3400	3400	3400	3400	3400	3400	3400	3400
5 A	133	151	147	166	3400	3400	3400	3400	3400	3400	3400	3400
6 A	431	557	475	614	3400	3400	3400	3400	3400	3400	3400	3400
7 A	1280	1530	1411	1687	1500	1500	1500	1500	1400	1400	1400	1400
8 A	1681	2445	1853	2696	1500	1500	1500	1500	1400	1400	1400	1400
9 A	1401	1658	1545	1828	1500	1500	1500	1500	1400	1400	1400	1400
10 A	1473	1486	1624	1638	1500	1500	1500	1500	1400	1400	1400	1400
11 A	1697	1607	1871	1772	1500	1500	1500	1500	1400	1400	1400	1400
12 P	1835	1958	2023	2159	1500	1500	1500	1500	1400	1400	1400	1400
1 P	1735	1820	1913	2007	1500	1500	1500	1500	1400	1400	1400	1400
2 P	1810	1903	1996	2098	1500	1500	1500	1500	1400	1400	1400	1400
3 P	2211	1722	2438	1899	1500	1500	1500	1500	1400	1400	1400	1400
4 P	2482	2111	2736	2327	1500	1500	1500	1500	1400	1400	1400	1400
5 P	2606	2303	2873	2539	3400	3400	3400	3400	3400	3400	3400	3400
6 P	1965	1857	2166	2047	3400	3400	3400	3400	3400	3400	3400	3400
7 P	1422	1335	1568	1472	3400	3400	3400	3400	3400	3400	3400	3400
8 P	1238	1113	1365	1227	3400	3400	3400	3400	3400	3400	3400	3400
9 P	1162	1091	1281	1203	3400	3400	3400	3400	3400	3400	3400	3400
10 P	825	867	910	956	3400	3400	3400	3400	3400	3400	3400	3400
11 P	607	570	669	628	3400	3400	3400	3400	3400	3400	3400	3400
Total	29034	29177	32010	32168	62600	62600	62600	62600	61600	61600	61600	61600

SUMMARY OUTPUT traffic method	7A-5P, No Publicity capacity=1500		7A-5P, Publicity capacity=1500		7A-5P, No Publicity lower decrease		7A-5P, Publicity lower decrease	
direction	SE	NW	SE	NW	SE	NW	SE	NW
total user cost	$32,724	$34,553	$24,425	$25,731	$40,793	$43,511	$29,307	$30,993
user cost of delays	$25,737	$27,097	$14,560	$15,292	$33,712	$35,697	$20,428	$21,532
user cost of decreases	$6,987	$7,456	$9,865	$10,439	$7,081	$7,814	$8,879	$9,461
maximum backup (V)	101	224	0	0	443	335	101	81
maximum backup length (lane mi)	0.6	1.3	0.0	0.0	2.5	1.9	0.6	0.5
maximum delay (min.)	14.2	19.1	8.9	8.8	26.9	24.5	14.2	13.6
average delay (min)	4.5	5.7	3.3	3.5	7.1	7.6	4.5	4.8
total delay, except diversions (V hr)	1893	2511	1349	1417	3124	3308	1893	1996
total vehicles canceled(V)	3343	2824	3772	3991	2651	2924	3343	3562
total vehicles diverted (V)	3343	2931	3772	3991	2779	3067	3343	3562
total decrease in demand (V)	6686	5754	7544	7983	5430	5991	6686	7124
% decrease in demand	16.9%	17.9%	23.6%	24.8%	17.0%	18.6%	20.9%	22.1%
delay per diverted vehicle (min)	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
total diversion delay (V hr)	288	252	325	344	239	264	288	307
average delay, including diversions (min)	4.4	5.7	3.6	3.8	6.9	7.3	4.6	4.8
total delay, including diversions (V hr)	2181	2764	1674	1761	3364	3573	2181	2302
user cost / design demand	$1.02	$1.07	$0.76	$0.80	$1.27	$1.35	$0.92	$0.96
delay cost / actual demand	$0.97	$1.03	$0.60	$0.63	$1.27	$1.36	$0.81	$0.86
Auto ON Print: ON Now: OK validity of output	VALID	VALID	VALID	VALID	VALID	VALID	VALID	VALID

You can copy these values into impact sheet

Fig. 2-11 Summary View of Traffic Sheet for Sensitivity Analysis

For example, in Fig. 2-6, Pg. 2-13, for 12A-1P, (average historical demand) = (SE % lane-closed) * (SE historical demand) + (NW % lane-closed) * (NW historical demand) = (50%) * (436) + (50%) * (416) = 426. We know US 00 Overlay has the same quantity of construction work in both directions. We look at traffic demand shown in Fig. 2-6, and we see some significant differences in hourly historical demand, but peaks and valleys occur at the same time in both directions. Therefore, we will use average historical demand to calculate period cost, and user cost on which period cost is based.

If the two directions are so different that they need different period costs in Special Provisions, we will separately calculate period cost for each direction. We would use the same method for each direction that we use here for the average of the two directions. Sec. 2.4.2.3.7, pg. 2-50 shows an example of these calculations for US 00 Overlay.

2.4.1.3 Need for Period Length < 1 hr

The workday or lane closure may start or end at other than a whole hour, so we need to be able to calculate and specify period cost for periods that are less than an hour. The smallest time period for which we normally specify period cost is 15 min. CO^3 accommodates minimum periods of 15 min, 20 min, and 30 min, as well as one hour. The CO^3 Traffic Sheet will not calculate user cost for more than 24 periods, so we perform additional calculations for 24 hours of periods shorter than one hour.

2.4.1.4 Nighttime Work

Project analysis using the CO^3 system indicates that US 00 Overlay should be performed at night. Examination of design demand indicates a contractor can work anytime between 8P and 8A without causing unacceptable congestion. A contractor will want to work as few hours and as few nights as possible, so there is no particular reason to constrain or provide incentives to work as few nights as possible. Similarly, a contractor should need no incentive or disincentive regarding number of nighttime lane closures, because the contractor will want to avoid the labor cost of closing a lane unnecessarily. Therefore, there is no real need to specify contract period cost in the Special Provisions for US 00 Overlay, if it is done at night. So we will not perform further calculations or analysis for nighttime work on US 00 Overlay.

2.4.1.5 Daytime Work

We determined in Sec. 2.3.3.4, pg. 2-24 that the work should be done at night, if practical, and for which there was no need to perform additional calculations related to implementation. However, the purpose of the Example Problem is to demonstrate the use of the CO^3 system. So, for the remainder of this example, we will assume nighttime construction is not practical, and this example implementation will be for daytime construction. We will use CO^3 to demonstrate calculation of each period's lane-closed cost = user cost caused by closure during the time period. This provides data from which we will calculate contract period cost for Special Provisions, primarily for daytime work on this project.

2.4.1.6 Period Cost

Project implementation includes selecting clauses and values to include in Special Provisions. **Period cost** is the term we use for such values specified in the Special Provisions for contract costs per time period. This includes **contract period cost** for periods in which construction impacts traffic. Contract period cost can be shown in the contract in various forms, including as liquidated damages, incentives or disincentives, adjustment values for A + B contracts, or rent-a-lane charges. The basis for selecting contract period cost for a project is user cost caused by construction during the relevant periods. For US 00 Overlay, for example, we can have a period cost for closing a lane from 4P-5P. CO^3 provides tools to calculate user cost and period cost: Sec. 2.4.2.2 demonstrates calculation of user cost on US 00 Overlay, and Sec. 2.4.2.3, pg. 2-45 demonstrates calculation of period cost.

2.4.2 SINGLE METHOD: CLOSURES ARE NOT ANNOUNCED

2.4.2.1 Introduction

The most common method of maintaining traffic is to close and open one or more lanes for alternating periods of time. An example of this is the Standard Method for US 00 Overlay, which is to close a lane 7A-5P to perform work and open it at 5P when work is completed for the day. There are only two scenarios for the road: (1) one lane closed and one lane open in one direction and two lanes open in the other direction or (2) two lanes open in both directions. In this most common case, there are user costs for only one scenario, which is the time a lane is closed. There are no user costs when all lanes are open. Therefore, we calculate daily and project user cost and period cost based only on the user cost and period cost for one scenario. These calculations are described in detail in this section.

User cost calculations where closures are “Not Announced” are described in Sec. 2.4.2.2. These include Traffic Sheet calculations (in Sec. 2.4.2.2.1), manual calculations based on Traffic Sheet output (in Sec. 2.4.2.2.2, pg. 2-35), and calculations using the Daily Sheet (in Sec. 2.4.2.2.3, pg. 2-36). Calculations of period costs for “Not Announced” using the Daily Sheet are described in Sec. 2.4.2.3, pg 2-45. and the applications of CO^3 to Special Provisions are described in Sec. 2.4.2.4, pg. 2-54.

A parallel description for calculating user cost and period cost and for using Special Provisions for multiple methods, which have user cost for more than one scenario for each time period, is presented in Sec. 2.4.3, pg. 2-57.

2.4.2.2 User Cost

2.4.2.2.1 Traffic Sheet Calculations

2.4.2.2.1.1 Period Length = 1 hr

We will calculate **user cost** for each hour, for a lane being closed all 24 hours. This will provide a basis for calculating user cost for each period. We first average each hour’s historical demand for both directions, shown in Fig. 2-6, Pg. 2-13, and we enter the resulting average historical demand in both historical demand columns in the Summary View of the Traffic Sheet, as shown in Fig. 2-12. We enter input, under Method 1 in Fig. 2-12 for “24 hr, Not Announced”, for 24 hour closure, for which each hour’s **capacity** = 1400, and we click the Calculate button on the left column under Method 1, to compute user cost, as shown in summary output in the Summary View. However, we are primarily interested in Fig. 2-13, the Combined View (or the Overall View), because it shows output for each hour. In the user cost column of Fig. 2-13 we read the user cost for each of the 24 hours. For example, user cost = $2,088 per day for closing a lane 7A-8A, and user cost = $4,509 per day for closing a lane 8A-9A.

Also, we note that **end of period backu**p ≠ 0 for all periods. This indicates there will be backup in some period when lane closure has not been announced in advance. Therefore, the user cost for all periods is not independent of closure in other periods. For example, user cost = $4,509 per day for closing a lane 8A-9A. In the backup eop column, we see that 7A-8A does not have end-of-period backup, but 8A-9A does. This indicates that 7A-8A user cost is independent of lane closure in adjacent periods, but 8A-9A user cost is not. In Sec. 1.7.2.2, pg. 1-66 we discuss inaccuracies in calculating user cost of periods that have backup.

2.4.2.2.1.2 Period Length < 1 hr

We can calculate user cost for period length =15, 20, or 30 min. with the computer by inputting appropriate values for period length, threshold capacities, capacity, and historical demand. We adjust the values of any variable *x* by the ratio between period length = *t* and 60 min using the following equation,

$$x_t = x_{60}\left(\frac{t}{60}\right) \qquad (32)$$

For example, (capacity for period length = 15 min) = (capacity for period length = 60 min) * (15 / 60). For closed lane capacity = 1400 VPH, (8:00A-8:15A capacity) = (1400) * (15 / 60) = 1400 / 4 = 350 V/period. Fig. 2-14 shows a Summary View for 24 periods of 15 min., for 7A-1P.

Fig. 2-15 is the Combined View for the left column under Method 2, in which a lane is closed 7A-1P, which is "Not Announced". In the user cost column, we can read the user cost for each 15 min period. Our inspection of Fig. 2-15 shows that some periods have end-of-period backup, others do not. Within any hour, 15 min periods that are not preceded by backup and which have no end-of-period backup all have the same user cost. For example, 7A-7:15A user cost = $526 = 7:15A-7:30A user cost = 7:30A-7:45A user cost = 7:45A-8A user cost. However, periods within an hour that are preceded by or that have end-of-period backup have different user costs. For example, 8A-8:15A user cost = $1,023 ≠ 8:15A-8:30A user cost = 1,131 ≠ 8:30A-8:45A user cost = $1,192 ≠ 8:45A-9A user cost = $1,228.

The Traffic Sheet can calculate only 24 periods, so it takes more than one Traffic Sheet to calculate user cost for all periods when period length < 1 hr. For example, 24 periods of 15 min. total only 6 hr. Therefore, four Traffic Sheets are required to calculate 24 hours of 15-min. periods. This is much more cumbersome than calculating user cost for 1-hr periods. For this reason, we usually calculate user cost for periods under 1 hr using user cost of 1-hr periods, as shown below in Sec. 2.4.2.2.3.

We use another Traffic Sheet to compute user costs for the six hours of 15 min periods, from 1P-7P, that follow 7A-1P. Fig. 2-16 is the Combined Sheet for 1P-7P that follows Fig. 2-15. The 1P-7P input is identical to 7A-1P input, except for design demand and start-of-period backup. We see in Fig. 2-15 that 12P-1P **end-of-period backup** = 54 V. Therefore, **backup at start** for "Not Announced" = 54 V, which we see in Fig. 2-16.

SummaryView

Copy This Sheet	period length (min)	60	PROJECT INFORMATION		REPORT INFORMATION
Update	annual traffic growth (%)	5.00%	PROJECT TITLE	US 00 Overlay	REPORT TITLE: DETAILED USER COST REPORT
	years of growth	2		Example Problem	SUMMARY VIEW
VEHICLE INPUT	cars	trucks	Paste Values C.S.	90000	DIVISION
design demand (%)	90.0%	10.0%	JOB #	00000	REPORT BY: R. I. Carr
user cost per hour ($/V hr)	$10.79	$10.79	START DATE	6/00/98	REPORT DATE: 1/2/97
user cost per mile, ($/V mi)	$0.30	$1.00	NOTES:		
user cost per cancellation, ($/V)	$1.00	$2.00			

METHOD INPUT		METHOD 1		METHOD 2		METHOD 3		METHOD 4	
	method title	24 hr, Not Announced		24 hr, Announced		24 Alt. Not Announced		7A-5P A; 5P-7P NA	
DISTANCE AND SPEED	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	2.0	see delay	2.0	see delay	2.0	see delay	2.0	see delay
	normal travel	2.0	65	2.0	65	2.0	65	2.0	65
diversion	method travel	12.0	50	12.0	50	12.0	50	12.0	50
	normal travel	10.0	65	10.0	65	10.0	65	10.0	65
SPEED DELAY		threshold	range	threshold	range	threshold	range	threshold	range
	capacity for speed delay (V/period)	1400		1400		1400		1400	
	speed (when D~0) (mph)	45		45		45		45	
	speed (when D=C) (mph)	10		10		10		10	
DECREASE TO DEMAND		threshold	range	threshold	range	threshold	range	threshold	range
	capacity for decreases to design demand (V/period)	1400		1400		1400		1400	1399
	canceled cars (with no delay) (%)	5.0%				5.0%			5.0%
	canceled trucks (with no delay) (%)								
	canceled cars (with delay) (%/min)	1.0%		3.0%		1.0%		3.0%	1.0%
	canceled trucks (with delay) (%/min)			1.0%				1.0%	
	diverted cars (with no delay) (%)	5.0%				5.0%			5.0%
	diverted trucks (with no delay) (%)								
	diverted cars (with delay) (%/min)	1.0%		3.0%		1.0%		3.0%	1.0%
	diverted trucks (with delay) (%/min)	0.5%		1.0%		0.5%		1.0%	0.5%
OTHER USER COST INPUT Update		cars	trucks	cars	trucks	cars	trucks	cars	trucks
	other user cost per actual demand ($/V)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	user cost per diversion ($/V)	$1.53	$2.93	$1.53	$2.93	$1.53	$2.93	$1.53	$2.93
	Paste Values	Calculate	Calculate	Calculate	Calculate	Calculate	Calculate	Calculate	Calculate

Summary | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

PERIOD INPUT			backup at start (V)		0	0	0	0	0	0	0	0
direction	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Avg	Even	Odd	Avg	Avg
period	historical demand		design demand		capacity		capacity		capacity		capacity	
(hr)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)
12 A	426	426	470	470	1400		1400	3400	1400	3400	3400	3400
1 A	266	266	293	293	1400		1400	3400	3400	1400	3400	3400
2 A	174	174	191	191	1400		1400	3400	1400	3400	3400	3400
3 A	97	97	107	107	1400		1400	3400	3400	1400	3400	3400
4 A	104	104	115	115	1400		1400	3400	1400	3400	3400	3400
5 A	142	142	157	157	1400		1400	3400	3400	1400	3400	3400
6 A	494	494	545	545	1400		1400	3400	1400	3400	3400	3400
7 A	1405	1405	1549	1549	1400		1400	1400	3400	1400	1400	1400
8 A	2063	2063	2274	2274	1400		1400	1400	1400	3400	1400	1400
9 A	1530	1530	1686	1686	1400		1400	1400	3400	1400	1400	1400
10 A	1480	1480	1631	1631	1400		1400	1400	1400	3400	1400	1400
11 A	1652	1652	1821	1821	1400		1400	1400	3400	1400	1400	1400
12 P	1897	1897	2091	2091	1400		1400	1400	1400	3400	1400	1400
1 P	1778	1778	1960	1960	1400		1400	1400	3400	1400	1400	1400
2 P	1857	1857	2047	2047	1400		1400	1400	1400	3400	1400	1400
3 P	1967	1967	2168	2168	1400		1400	1400	3400	1400	1400	1400
4 P	2297	2297	2532	2532	1400		1400	1400	1400	3400	1400	1400
5 P	2455	2455	2706	2706	1400		1400	3400	3400	1400	1399	3400
6 P	1911	1911	2107	2107	1400		1400	3400	1400	3400	1399	3400
7 P	1379	1379	1520	1520	1400		1400	3400	3400	1400	3400	3400
8 P	1176	1176	1296	1296	1400		1400	3400	1400	3400	3400	3400
9 P	1127	1127	1242	1242	1400		1400	3400	3400	1400	3400	3400
10 P	846	846	933	933	1400		1400	3400	1400	3400	3400	3400
11 P	589	589	649	649	1400		1400	3400	3400	1400	3400	3400
Total	29105.5	29105.5	32089	32089	33600	0	33600	61600	57600	57600	57598	61600

SUMMARY OUTPUT	traffic method	24 hr, Not Announced		24 hr, Announced		24 Alt. Not Announced		7A-5P A; 5P-7P NA	
	direction	Avg	Avg	Avg	7A-5P	Even	Odd	5P closed	5P open
	total user cost	$54,983		$38,711	$25,936	$26,236	$24,754	$37,053	$25,936
	user cost of delays	$42,642		$22,905	$15,237	$20,556	$19,360	$23,882	$15,237
	user cost of decreases	$12,341		$15,806	$10,698	$5,681	$5,394	$13,170	$10,698
	maximum backup (V)	260		0	0	264	334	268	0
	maximum backup length (lane mi)	1.5		0.0	0.0	1.5	1.9	1.5	0.0
	maximum delay (min.)	21.3		9.2	8.8	19.7	21.7	21.6	8.8
	average delay (min)	10.5		6.4	3.5	4.1	3.9	6.0	3.5
You can copy these values into impact sheet	total delay, except diversions (V hr)	3952		2123	1412	1905	1794	2213	1412
	total vehicles canceled(V)	4671		6044	4091	2154	2047	5022	4091
	total vehicles diverted (V)	4850		6044	4091	2233	2121	5062	4091
	total decrease in demand (V)	9521		12087	8181	4387	4168	10084	8181
	% decrease in demand	29.7%		37.7%	25.5%	13.7%	13.0%	31.4%	25.5%
	delay per diverted vehicle (min)	5.2		5.2	5.2	5.2	5.2	5.2	5.2
	total diversion delay (V hr)	418		521	352	192	183	436	352
	average delay, including diversions (min)	9.6		6.1	3.8	4.2	3.9	5.9	3.8
	total delay, including diversions (V hr)	4370		2643	1765	2097	1977	2649	1765
	user cost / design demand	$1.71		$1.21	$0.81	$0.82	$0.77	$1.15	$0.81
	delay cost / actual demand	$1.89		$1.15	$0.64	$0.74	$0.69	$1.09	$0.64
Auto: ON Print: ON Now: OK	validity of output	VALID	NOT VALID	VALID	VALID	VALID	VALID	VALID	VALID

Fig. 2-12 Summary View for Average Historical Demand

Combined View

period length (min)	60	
annual traffic growth (%)	0	
years of growth	2	
VEHICLE INPUT	cars	trucks
design demand (%)	90.0%	10.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION	
PROJECT	US 00 Overlay
TITLE	Example Problem
C.S.	90000
JOB #	00000
START DATE	6/00/98

REPORT INFORMATION	
REPORT	DETAILED USER COST REPORT
TITLE	COMBINED VIEW
DIVISION	
REPORT BY	R. I. Carr
REPORT DATE	1/2/97

NOTES:

METHOD INPUT		METHOD 1	
method title		24 hr, Not Announced	
DISTANCE AND SPEED	(mi) (mph)	distance	speed
work zone	method travel	2	see delay
	normal travel	2	65
diversion	method travel	12	50
	normal travel	10	65
SPEED DELAY		threshold	range
capacity for speed delay (V/period)		1400	
speed (when D~0) (mph)		45	
speed (when D=C) (mph)		10	
DECREASE TO DEMAND		threshold	range
capacity for decreases to design demand (V/period)		1400	
canceled cars (with no delay) (%)		5.0%	
canceled trucks (with no delay) (%)			
canceled cars (with delay) (%/min)		1.0%	
canceled trucks (with delay) (%/min)			
diverted cars (with no delay) (%)		5.0%	
diverted trucks (with no delay) (%)			
diverted cars (with delay) (%/min)		1.0%	
diverted trucks (with delay) (%/min)		0.5%	

SUMMARY OUTPUT	
traffic method	24 hr, Not Announced
direction	Avg
total user cost	$54,983
user cost of delays	$42,642
user cost of decreases	$12,341
maximum backup (V)	260
maximum backup length (lane mi)	1.5
maximum delay (min.)	21.3
average delay (min)	10.5
total delay, except diversions (V hr)	3,952
total vehicles canceled(V)	4,671
total vehicles diverted (V)	4,850
total decrease in demand (V)	9,521
% decrease in demand	29.7%
delay per diverted vehicle (min)	5.2
total diversion delay (V hr)	418
average delay, including diversions (min)	9.6
total delay, including diversions (V hr)	4,370
user cost / design demand	$1.71
delay cost / actual demand	$1.89

OTHER USER COST INPUT	cars	trucks
other user cost per vehicle ($/V)	$0.00	$0.00
user cost per diversion ($/V)	$1.53	$2.93

Combo Go To: Summary Overall Traffic User Cost Combined Print: This View Summary Overall All Setup

Direction:	Avg	backup at start (V)		0								
period (hr)	capacity (V/period)	actual demand (V/period)	total decrease (V/period)	total delay (V/period)	backup eop (V)	maximum delay (min)	average backup delay (min)	average speed delay (min)	decrease cost ($)	delay cost ($)	user cost ($)	delay cost / actual demand ($/V)
12 A	1400	413	56	11	0	1.63	0.0	1.6	$72	$121	$193	$0.29
1 A	1400	261	33	5	0	1.14	0.0	1.1	$42	$54	$95	$0.21
2 A	1400	171	21	3	0	0.96	0.0	1.0	$26	$29	$56	$0.17
3 A	1400	96	11	1	0	0.86	0.0	0.9	$14	$15	$29	$0.16
4 A	1400	102	12	1	0	0.87	0.0	0.9	$15	$16	$32	$0.16
5 A	1400	140	17	2	0	0.91	0.0	0.9	$21	$23	$44	$0.16
6 A	1400	476	68	15	0	1.90	0.0	1.9	$87	$163	$250	$0.34
7 A	1400	1,192	357	151	0	7.59	0.0	7.6	$461	$1,627	$2,088	$1.36
8 A	1400	1,528	747	328	128	15.62	2.7	10.2	$969	$3,540	$4,509	$2.32
9 A	1400	1,196	490	216	0	15.62	1.7	9.2	$635	$2,332	$2,967	$1.95
10 A	1400	1,239	392	168	0	8.13	0.0	8.1	$507	$1,811	$2,319	$1.46
11 A	1400	1,341	480	210	0	9.39	0.0	9.4	$622	$2,264	$2,885	$1.69
12 P	1400	1,463	628	277	63	12.58	1.2	10.2	$814	$2,991	$3,804	$2.04
1 P	1400	1,353	606	267	16	12.86	1.7	10.2	$786	$2,886	$3,672	$2.13
2 P	1400	1,431	615	272	48	11.91	1.2	10.2	$798	$2,931	$3,729	$2.05
3 P	1400	1,445	723	317	93	14.13	3.0	10.2	$939	$3,421	$4,360	$2.37
4 P	1400	1,520	1,012	424	213	19.33	6.6	10.2	$1,315	$4,574	$5,889	$3.01
5 P	1400	1,447	1,259	489	260	21.29	10.1	10.2	$1,638	$5,279	$6,917	$3.65
6 P	1400	1,230	877	362	90	21.29	7.5	10.2	$1,140	$3,901	$5,042	$3.17
7 P	1400	1,138	382	165	0	13.99	0.7	8.1	$494	$1,785	$2,279	$1.57
8 P	1400	1,037	259	103	0	5.94	0.0	5.9	$334	$1,108	$1,442	$1.07
9 P	1400	1,002	240	93	0	5.60	0.0	5.6	$310	$1,008	$1,318	$1.01
10 P	1400	784	149	49	0	3.75	0.0	3.7	$191	$529	$719	$0.67
11 P	1400	563	86	22	0	2.32	0.0	2.3	$110	$235	$346	$0.42
TOT	33600	22,568	9,521	3,952					$12,341	$42,642	$54,983	$1.89
MAX	1400	1,528	1,259	489	260	21.29	10	10.15	$1,638	$5,279	$6,917	$3.65
MIN	1400	96	11	1	0	0.86	0	0.86	$14	$15	$29	$0.16

Fig. 2-13 Combined View for "24 hr, Not Announced", Average Design Demand

SummaryView

Copy This Sheet	period length (min)	15	
	annual traffic growth (%)	5.00%	
e	years of growth	2	
VEHICLE INPUT		cars	trucks
	design demand (%)	90.0%	10.0%
	user cost per hour ($/V hr)	$10.79	$10.79
	user cost per mile, ($/V mi)	$0.30	$1.00
	user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION		
PROJECT TITLE	US 00 Overlay Example Problem	
Paste Values	C.S.	90000
	JOB #	00000
	START DATE	6/00/98

REPORT INFORMATION		
REPORT TITLE	DETAILED USER COST REPORT TRAFFIC SHEET	
	DIVISION	
	REPORT BY	R. I. Carr
	REPORT DATE	1/2/97

NOTES:

METHOD INPUT	METHOD 1		METHOD 2		METHOD 3		METHOD 4	
method title	Announced		Not Announced					
DISTANCE AND SPEED (mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone: method travel	2.0	see delay	2.0	see delay	2.0	see delay	2.0	see delay
work zone: normal travel	2.0	65	2.0	65	2.0	65	2.0	65
diversion: method travel	12.0	50	12.0	50	12.0	50	12.0	50
diversion: normal travel	10.0	65	10.0	65	10.0	65	10.0	65
SPEED DELAY	threshold	range	threshold	range	threshold	range	threshold	range
capacity for speed delay (V/period)	350		350		350		350	
speed (when D~0) (mph)	45		45		45		45	
speed (when D=C) (mph)	10		10		10		10	
DECREASE TO DEMAND	threshold	range	threshold	range	threshold	range	threshold	range
capacity for decreases to design demand (V/period)	350		350					
canceled cars (with no delay) (%)			5.0%					
canceled trucks (with no delay) (%)								
canceled cars (with delay) (%/min)	3.0%		1.0%					
canceled trucks (with delay) (%/min)	1.0%							
diverted cars (with no delay) (%)			5.0%					
diverted trucks (with no delay) (%)								
diverted cars (with delay) (%/min)	3.0%		1.0%					
diverted trucks (with delay) (%/min)	1.0%		0.5%					

OTHER USER COST INPUT (Updat)	cars	trucks	cars	trucks	cars	trucks	cars	trucks
other user cost per actual demand ($/V)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
user cost per diversion ($/V)	$1.53	$2.93	$1.53	$2.93	$1.53	$2.93	$1.53	$2.93
Paste Values	Calculate	Calculate	Calculate	Calculate	Calculate	Calculate	Calculate	Calculate

Summary | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

PERIOD INPUT			backup at start (V)		0	0	0	0				
direction	7A-1P	7:45A-1P	Avg	Avg	7A-1P	7:45A-1P	7A-1P	7:45A-1P				
period			design demand		capacity		capacity		capacity		capacity	
(hr)			(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)	(V/period)
7 A	351	351	387	387	350	850	350	850				
	351	351	387	387	350	850	350	850				
	351	351	387	387	350	850	350	850				
	351	351	387	387	350	350	350	350				
8 A	516	516	569	569	350	350	350	350				
	516	516	569	569	350	350	350	350				
	516	516	569	569	350	350	350	350				
	516	516	569	569	350	350	350	350				
9 A	382	382	422	422	350	350	350	350				
	382	382	422	422	350	350	350	350				
	382	382	422	422	350	350	350	350				
	382	382	422	422	350	350	350	350				
10 A	370	370	408	408	350	350	350	350				
	370	370	408	408	350	350	350	350				
	370	370	408	408	350	350	350	350				
	370	370	408	408	350	350	350	350				
11 A	413	413	455	455	350	350	350	350				
	413	413	455	455	350	350	350	350				
	413	413	455	455	350	350	350	350				
	413	413	455	455	350	350	350	350				
12 P	474	474	523	523	350	350	350	350				
	474	474	523	523	350	350	350	350				
	474	474	523	523	350	350	350	350				
	474	474	523	523	350	350	350	350				
Total	10024.5	10024.5	11052	11052	8400	9900	8400	9900				

SUMMARY OUTPUT		traffic method	Announced		Not Announced					
		direction	7A-1P	7:45A-1P	7A-1P	7:45A-1P				
		total user cost	$14,034	$12,711	$18,618	$16,938				
		user cost of delays	$8,376	$7,553	$14,591	$13,281				
		user cost of decreases	$5,658	$5,158	$4,027	$3,657				
		maximum backup (V)	0	0	0	113				
		maximum backup length (lane mi)	0.0	0.0	0.0	0.6				
You can copy these values into impact sheet		maximum delay (min.)	8.2	8.2	8.2	15.0				
		average delay (min)	6.9	5.9	6.9	9.0				
		total delay, except diversions (V hr)	776	700	776	1231				
		total vehicles canceled(V)	2163	1972	2163	1385				
		total vehicles diverted (V)	2163	1972	2163	1437				
		total decrease in demand (V)	4327	3945	4327	2822				
		% decrease in demand	39.1%	35.7%	28.1%	25.5%				
		delay per diverted vehicle (min)	5.2	5.2	5.2	5.2				
		total diversion delay (V hr)	186	170	186	124				
		average delay, including diversions (min)	6.5	5.7	5.7	8.4				
		total delay, including diversions (V hr)	963	870	963	1355				
		user cost / design demand	$1.27	$1.15	$1.68	$1.53				
		delay cost / actual demand	$1.25	$1.06	$1.84	$1.61				
Auto ON	Print: ON	Now OK validity of output	VALID	VALID	VALID	VALID	NOT VALID	NOT VALID	NOT VALID	NOT VALID

Fig. 2-14 Summary View for 7A-1P, Period Length = 15 min.

Combined View

period length (min)	15	
annual traffic growth (%)	0	
years of growth	2	
VEHICLE INPUT	cars	trucks
design demand (%)	90.0%	10.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION	
PROJECT TITLE	US 00 Overlay
C.S.	
JOB #	90000
START DATE	00000

REPORT INFORMATION	
REPORT TITLE	TRAFFIC SHEET
DIVISION	
REPORT BY	
REPORT DATE	R. I. Carr

NOTES:

METHOD INPUT	METHOD 1	
method title	Not Announced	
DISTANCE AND SPEED (mi) (mph)	distance	speed
work zone — method travel	2	see delay
work zone — normal travel	2	65
diversion — method travel	12	50
diversion — normal travel	10	65
SPEED DELAY	threshold	range
capacity for speed delay (V/period)	350	
speed (when D~0) (mph)	45	
speed (when D=C) (mph)	10	
DECREASE TO DEMAND	threshold	range
capacity for decreases to design demand (V/period)	350	
canceled cars (with no delay) (%)	0.05	
canceled trucks (with no delay) (%)		
canceled cars (with delay) (%/min)	0.01	
canceled trucks (with delay) (%/min)		
diverted cars (with no delay) (%)	0.05	
diverted trucks (with no delay) (%)		
diverted cars (with delay) (%/min)	0.01	
diverted trucks (with delay) (%/min)	0.005	
OTHER USER COST INPUT	cars	trucks
other user cost per vehicle ($/V)	$0.00	$0.00
user cost per diversion ($/V)	$1.53	$2.93

SUMMARY OUTPUT	
traffic method	Not Announced
direction	7A-1P
total user cost	$18,618
user cost of delays	$14,591
user cost of decreases	$4,027
maximum backup (V)	113
maximum backup length (lane mi)	0.6
maximum delay (min.)	15.0
average delay (min)	10.2
total delay, except diversions (V hr)	1,352
total vehicles canceled(V)	1,526
total vehicles diverted (V)	1,583
total decrease in demand (V)	3,109
% decrease in demand	28.1%
delay per diverted vehicle (min)	5.2
total diversion delay (V hr)	136
average delay, including diversions (min)	9.4
total delay, including diversions (V hr)	1,489
user cost / design demand	$1.68
delay cost / actual demand	$1.84

Combo | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

Direction: 7A-1P | backup at start (V) 0

period (hr)	capacity (V/period)	actual demand (V/period)	total decrease (V/period)	total delay (V/period)	backup eop (V)	maximum delay (min)	average backup delay (min)	average speed delay (min)	decrease cost ($)	delay cost ($)	user cost ($)	delay cost / actual demand ($/V)
7 A	350	297	90	38	0	7.67	0.0	7.7	$116	$410	$526	$1.38
	350	297	90	38	0	7.67	0.0	7.7	$116	$410	$526	$1.38
	350	297	90	38	0	7.67	0.0	7.7	$116	$410	$526	$1.38
	350	297	90	38	0	7.67	0.0	7.7	$116	$410	$526	$1.38
8 A	350	400	169	75	50	12.23	1.0	10.2	$219	$805	$1,023	$2.01
	350	381	187	82	81	13.62	2.8	10.2	$243	$888	$1,131	$2.33
	350	370	199	87	101	14.47	3.9	10.2	$258	$934	$1,192	$2.53
	350	362	206	89	113	15.00	4.6	10.2	$268	$960	$1,228	$2.65
9 A	350	279	143	63	42	15.00	3.3	10.2	$186	$675	$860	$2.42
	350	302	120	53	0	11.94	0.7	9.7	$155	$568	$723	$1.88
	350	317	105	45	0	8.57	0.0	8.6	$136	$488	$624	$1.54
	350	317	105	45	0	8.57	0.0	8.6	$136	$488	$624	$1.54
10 A	350	309	99	42	0	8.21	0.0	8.2	$128	$457	$584	$1.48
	350	309	99	42	0	8.21	0.0	8.2	$128	$457	$584	$1.48
	350	309	99	42	0	8.21	0.0	8.2	$128	$457	$584	$1.48
	350	309	99	42	0	8.21	0.0	8.2	$128	$457	$584	$1.48
11 A	350	334	121	53	0	9.53	0.0	9.5	$157	$572	$729	$1.71
	350	334	121	53	0	9.53	0.0	9.5	$157	$572	$729	$1.71
	350	334	121	53	0	9.53	0.0	9.5	$157	$572	$729	$1.71
	350	334	121	53	0	9.53	0.0	9.5	$157	$572	$729	$1.71
12 P	350	373	150	66	23	11.09	0.5	10.2	$194	$712	$906	$1.91
	350	365	158	70	38	11.73	1.3	10.2	$204	$751	$955	$2.06
	350	360	163	72	48	12.14	1.8	10.2	$211	$774	$985	$2.15
	350	356	166	73	54	12.44	2.2	10.2	$216	$791	$1,007	$2.22
TOT	8400	7,943	3,109	1,352					$4,027	$14,591	$18,618	$1.84
MAX	350	400	206	89	113	15.00	5	10.15	$268	$960	$1,228	$2.65
MIN	350	279	90	38	0	7.67	0	7.67	$116	$410	$526	$1.38

Fig. 2-15 Combined View for "Not Announced, 7A-1P" for Period Length = 15 min

Combined View

period length (min)	15	
annual traffic growth (%)	0	
years of growth	2	
VEHICLE INPUT	cars	trucks
design demand (%)	90.0%	10.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION	
PROJECT TITLE	US 00 Overlay
C.S.	
JOB #	90000
START DATE	00000
NOTES:	

REPORT INFORMATION	
REPORT TITLE	TRAFFIC SHEET
DIVISION	
REPORT BY	
REPORT DATE	R. I. Carr

METHOD INPUT		METHOD 1	
method title		Not Announced	
DISTANCE AND SPEED	(mi) (mph)	distance	speed
work zone	method travel	2	see delay
	normal travel	2	65
diversion	method travel	12	50
	normal travel	10	65
SPEED DELAY		threshold	range
capacity for speed delay (V/period)		350	
speed (when D~0) (mph)		45	
speed (when D=C) (mph)		10	
DECREASE TO DEMAND		threshold	range
capacity for decreases to design demand (V/period)		350	
canceled cars (with no delay) (%)		0.05	
canceled trucks (with no delay) (%)			
canceled cars (with delay) (%/min)		0.01	
canceled trucks (with delay) (%/min)			
diverted cars (with no delay) (%)		0.05	
diverted trucks (with no delay) (%)			
diverted cars (with delay) (%/min)		0.01	
diverted trucks (with delay) (%/min)		0.005	
OTHER USER COST INPUT		cars	trucks
other user cost per vehicle ($/V)		$0.00	$0.00
user cost per diversion ($/V)		$1.53	$2.93

SUMMARY OUTPUT	
traffic method	Not Announced
direction	1P-7P
total user cost	$29,461
user cost of delays	$22,880
user cost of decreases	$6,581
maximum backup (V)	232
maximum backup length (lane mi)	1.3
maximum delay (min.)	18.0
average delay (min)	5.7
total delay, except diversions (V hr)	1,060
total vehicles canceled(V)	1,158
total vehicles diverted (V)	1,203
total decrease in demand (V)	2,361
% decrease in demand	37.5%
delay per diverted vehicle (min)	5.2
total diversion delay (V hr)	104
average delay, including diversions (min)	7.2
total delay, including diversions (V hr)	1,164
user cost / design demand	$2.18
delay cost / actual demand	$2.71

Combo Go To: Summary Overall Traffic User Cost Combined Print: This View Summary Overall All Setup

Direction: 1P-7P		backup at start (V)		54								
period (hr)	capacity (V/period)	actual demand (V/period)	total decrease (V/period)	total delay (V/period)	backup eop (V)	maximum delay (min)	average backup delay (min)	average speed delay (min)	decrease cost ($)	delay cost ($)	user cost ($)	delay cost / actual demand ($/V)
1 P	350	336	154	68	40	12.47	2.0	10.2	$200	$732	$931	$2.18
	350	340	149	66	30	11.85	1.5	10.2	$194	$711	$904	$2.09
	350	343	146	65	23	11.44	1.1	10.2	$189	$696	$886	$2.03
	350	346	144	63	19	11.15	0.9	10.2	$186	$685	$871	$1.98
2 P	350	360	152	67	29	11.35	1.0	10.2	$197	$722	$919	$2.01
	350	357	155	68	36	11.63	1.4	10.2	$201	$738	$939	$2.07
	350	354	157	69	40	11.81	1.6	10.2	$204	$749	$953	$2.11
	350	353	159	70	43	11.93	1.7	10.2	$206	$755	$961	$2.14
3 P	350	369	173	76	62	12.81	2.3	10.2	$225	$823	$1,047	$2.23
	350	362	180	79	74	13.33	2.9	10.2	$233	$851	$1,085	$2.35
	350	358	184	81	82	13.67	3.3	10.2	$239	$869	$1,108	$2.43
	350	355	187	82	87	13.89	3.6	10.2	$243	$880	$1,122	$2.48
4 P	350	401	232	100	138	16.06	4.8	10.2	$302	$1,079	$1,381	$2.69
	350	380	253	106	168	17.36	6.6	10.2	$328	$1,143	$1,471	$3.00
	350	368	265	109	186	18.14	7.6	10.2	$344	$1,175	$1,519	$3.19
	350	361	272	110	197	18.60	8.2	10.2	$354	$1,192	$1,546	$3.30
5 P	350	376	301	120	223	19.71	9.0	10.2	$391	$1,295	$1,686	$3.45
	350	365	312	122	238	20.35	9.9	10.2	$405	$1,315	$1,720	$3.60
	350	359	318	123	247	20.72	10.4	10.2	$414	$1,324	$1,738	$3.69
	350	355	322	123	252	20.93	10.7	10.2	$418	$1,330	$1,748	$3.75
6 P	350	288	238	94	190	20.93	9.5	10.2	$310	$1,016	$1,327	$3.53
	350	310	217	90	149	18.29	7.3	10.2	$282	$970	$1,252	$3.13
	350	324	203	86	123	16.55	5.8	10.2	$264	$930	$1,194	$2.87
	350	333	194	83	106	15.42	4.9	10.2	$252	$900	$1,152	$2.71
TOT	8400	8,452	5,066	2,121					$6,581	$22,880	$29,461	$2.71
MAX	350	401	322	123	252	20.93	11	10.15	$418	$1,330	$1,748	$3.75
MIN	350	288	144	63	19	11.15	1	10.15	$186	$685	$871	$1.98

Fig. 2-16 Combined View for "Not Announced, 1P-7P" for Period Length = 15 min

2.4.2.2.2 Manual Calculations Using Traffic Sheet

2.4.2.2.2.1 General

We can use Eq. (24) from Sec. 1.7.2.3, pg. 1-69, which we repeat below, for manual calculation of user cost or period cost for period *j* through period *k*:

$$(cost)_{j \text{ to } k} = \sum_{i=j \text{ to } k} (cost)_i \qquad (24)$$

2.4.2.2.2.2 Period = 1 hr

We apply Eq. (24) to "Not Announced" to sum user cost from the Overall View, User Cost View, or Combined View. For example, using user cost in the Combined View of Fig. 2-13, 7A-5P *user cost* = 2,088 + 4,509 + 2,967 + 2,319 + 2,885 + 3,804 + 3,672 + 3,729 + 4,360 + 5,889 = $36,222

2.4.2.2.2.3 Period < 1 hr

We can apply Eq. (24) to user cost of periods less than 1 hr or to a mixture of periods of different lengths. For example, to calculate 7:45A-4:30P user cost, we apply Eq. (24) to output from three Traffic Sheets. From Fig. 2-15 we read 7:45A-8A user cost = $526. From Fig. 2-13 we read and calculate 8A-4P user cost = 4,509 + 2,967 + 2,319 + 2,885 + 3,804 + 3,672 + 3,729 + 4,360 = $28,245. From Fig. 2-16 we read and calculate 4P-4:30P user cost = 1,281 + 1,471 = $2,852. From these we calculate 7:45A-4:30P user cost = 526 + 28,245 + 2,852 = $31,623.

2.4.2.2.3 User Cost Calculations Using Daily Sheet

The Daily Cost Sheet (shortened to "daily" in the tabs at the bottom of the spreadsheet), also called the Daily Sheet, accommodates one **user cost** input per period. The Daily Sheet consists of five views:

- User Cost View, in which we input and report user cost for each hour and a portion of an hour. An example is Fig. 2-17.
- Period Cost View, which shows period costs as a rounded-off fraction of user cost. An example is Fig. 2-18.
- Detailed Cost View, from which we can more easily manually calculate user cost for time periods, including round-off and fractions of periods. An example is Fig. 2-19.
- Daily Cost View, which is an even more detailed view of period user cost, which includes a table of all possible traffic maintenance hours. An example is Fig. 2-21.
- Project Cost View, which calculates cost each day and total period costs for any arrangement of lane-closed hours, including actual lane-closed hours for the duration of the project. An example is Fig. 2-23.

2.4.2.2.3.1 User Cost View

The User Cost View (not to be confused with the User Cost View of the Traffic Sheet) is the first portion of the Daily Sheet (shortened to "daily" in the tabs) in the CO^3 Computer Model. We Copy and Paste Value the hourly user cost values from the Traffic Sheet Overall View, User Cost View, or Combined View, such as Fig. 2-13, into the User Cost View of the Daily Cost Sheet. We pasted the values from the Combined View in Fig. 2-13 to produce the Daily Sheet User Cost View of Fig. 2-17. We also enter method and traffic descriptions in the Daily Sheet. These descriptions usually differ from descriptions in the Traffic Sheet, because Traffic Sheet descriptions usually specify a set of hours of lane closure. The User Cost View calculates user cost for portions of one hour, according to the input of period length (which is 15 min in Fig. 2-17). The top few rows in Fig. 2-17, above the User Cost View, show the list of views in the Daily Cost Sheet and navigation buttons on which we can click to take us to an individual view.

Daily Cost Sheet Tables

User Cost View	Go To
Period Cost View	Period Cost
Detailed Cost View	Detailed Cost
Daily Cost View	Daily Cost
Project Cost View	Project Cost

User Cost View — Paste Values

Project:	US 00 Overlay (Example)	
By:	R. I. Carr, 7/1/97	
Other:		
Method:	No Publicity	
Traffic:	Lane Closed	
Print	User Cost per Period	
Period (min):	60	15
12 A - 1 A	$193	$48
1 A - 2 A	$95	$24
2 A - 3 A	$56	$14
3 A - 4 A	$29	$7
4 A - 5 A	$32	$8
5 A - 6 A	$44	$11
6 A - 7 A	$250	$62
7 A - 8 A	$2,088	$522
8 A - 9 A	$4,509	$1,127
9 A - 10 A	$2,967	$742
10 A - 11 A	$2,319	$580
11 A - 12 P	$2,885	$721
12 P - 1 P	$3,804	$951
1 P - 2 P	$3,672	$918
2 P - 3 P	$3,729	$932
3 P - 4 P	$4,360	$1,090
4 P - 5 P	$5,889	$1,472
5 P - 6 P	$6,917	$1,729
6 P - 7 P	$5,042	$1,260
7 P - 8 P	$2,279	$570
8 P - 9 P	$1,442	$360
9 P - 10 P	$1,318	$329
10 P - 11 P	$719	$180
11 P - 12 A	$346	$86
24 hr	$54,983	

Fig. 2-17 User Cost View for "Lane Closed, Not Announced".

2.4.2.2.3.2 Period Cost View

The Period Cost View of the Daily Sheet calculates hourly period cost as a rounded-off fraction of user cost, and it provides results in a simple format that is practical for printing in reports. The Period Cost View has four inputs, all of which are included in "Adjustments to User Cost". The Period Cost View has two print buttons: one button prints it Period Cost Input and the other button prints it without Period Cost Input. In this section, we want to use the Daily Sheet to calculate user cost, based on the values in the User Cost View. Therefore, we want no adjustments to user cost. Fig. 2-18 shows these null values for adjustments to user cost and the values that result in the Period Cost View, which are the same as in the User Cost View of Fig. 2-17.

From the Period Cost View we can calculate user cost for any lane closure times, in 15 min steps. For example, 7A-5P user cost = 2,088 + 4,509 + 2,967 + 2,319 + 2,885 + 3,804 + 3,672 + 3,729 + 4,360 + 5,889 = $36,222. 6:45A-5:30 user cost = (6:45A-7A user cost = 62) +

(7A-5P user cost = 36,222) + (5P-5:30P user cost = 2 * 1,729 = 3,458) = $39,742. 7:45A-4:30P user cost = (7A-5P user cost = 36,222) – (7A-7:45A user cost = 3 * 522 = 1,566) – (4:30P-5P user cost = 2 * 1,472 = 2,944) = $31,712. We can compare this to 7:45A-4:30P user cost = $31,623 calculated directly from Traffic Sheets in Sec. 2.4.2.2.1.2, Pg. 2-30.

Period Cost Input Print with Input

Fraction = P/U =		100%
Cost Threshold =		
Round-Off =		

Period Cost View

Project:	US 00 Overlay (Example)	
By:	R. I. Carr, 7/1/97	
Other:	From avg traffic sheet: M1	
Method:	No Publicity	
Traffic:	Lane Closed	
Print	Cost per Period	
Period (min):	60	15
12 A - 1 A	$193	$48
1 A - 2 A	$95	$24
2 A - 3 A	$56	$14
3 A - 4 A	$29	$7
4 A - 5 A	$32	$8
5 A - 6 A	$44	$11
6 A - 7 A	$250	$62
7 A - 8 A	$2,088	$522
8 A - 9 A	$4,509	$1,127
9 A - 10 A	$2,967	$742
10 A - 11 A	$2,319	$580
11 A - 12 P	$2,885	$721
12 P - 1 P	$3,804	$951
1 P - 2 P	$3,672	$918
2 P - 3 P	$3,729	$932
3 P - 4 P	$4,360	$1,090
4 P - 5 P	$5,889	$1,472
5 P - 6 P	$6,917	$1,729
6 P - 7 P	$5,042	$1,260
7 P - 8 P	$2,279	$570
8 P - 9 P	$1,442	$360
9 P - 10 P	$1,318	$329
10 P - 11 P	$719	$180
11 P - 12 A	$346	$86
24 hr	$54,983	

Fig. 2-18 Period Cost View of User Costs for "Lane Closed, Not Announced".

2.4.2.2.3.3 Detailed Cost View

The Detailed Cost View is basically a reorganization of Period Cost View data for more detailed reporting and easier manual calculation of period cost for multiple periods. The Detailed Cost View supports quick calculation of user cost and period cost for any combination of daily work start and finish at increments of 15 min., 20 min., 30 min., or 60 min. Fig. 2-19 shows the Detailed Cost View that is based on the cost per period values shown in the Period Cost View of Fig. 2-18.

The Detailed Cost View has two print buttons: one button prints it with examples of cumulative period cost and the other button prints it without the examples. Fig. 2-19 shows it printed with its examples. Two sets of examples are shown in the lower part of Fig. 2-19. The first set contains examples for whole hour periods, and the second contains examples for segments of hours. Fig. 2-19 shows values for 15-min segments (15, 30, and 45 min), because we entered

period = 15 at the top of the first "Period" column to the right of "60" in the User Cost View, Fig. 2-17. The examples shown at the bottom of Fig. 2-19 are for 15-min segments.

If 20-min. or 30-min. segmentation had been input to the User Cost View, the Detailed Cost View and its examples would be for 20- or 30-min. segments. For example, Fig. 2-20 is the same as Fig. 2-19, except that it is calculated for 20-min. segmentation input in its User Cost View. The column headings and the examples at the bottom are automatically adjusted to the 20-min input segmentation. The Detailed Cost View also automatically adjusts to 30-min. segmentation (not shown).

The Detailed Cost View has columns for Period Cost for each hour and for the sum of Period Cost, starting at midnight. For example, 1P-2P Period Cost = $3,672, and the sum of Individual Period Costs from 12A to 2P = $22,944. In addition, the Detailed Cost View has columns for segments of the hour. In Fig. 2-19, the input segmentation is 15 min.; therefore, values are shown for 15 min., 30 min., and 45 min. Each 15-min. Period Cost is one-fourth of its hour's 60-min Period Cost. For example, all 15-min. segments from 1P-2P have 15 min Period Cost = (1P-2P user cost) / (15 / 60) = 3,672 / 4 = $918. Similarly, the Period Cost for any 45-min. segment from 1P-2P = 3 * 15-min. Period Cost = 3 * 918 = $2,754. The general expression follows Eq. (32) in Sec. 2.4.2.2.3.3, pg. 2-38 and is described in Eq. (33), where t = **segment length** (min) during a 60-min period.

$$(period\ cost)_t = (period\ cost)_{60}\left(\frac{t}{60}\right) \qquad (33)$$

Calculations using the Detailed Cost View follow Eq. (24) in the same manner as shown in Sec.2.4.2.2.2, pg. 2-35. For example, 1P-3P user cost = 1P-2P user cost + 2P-3P user cost = $3,672 + 3,729 = $7,401. Similarly, 7A-5P user cost = [(12A-5P user cost) – (12A-7A user cost)] = 36,921 – 699 = $36,222. 6:45A-5:30P user cost can be calculated several ways.

1. 6:45A-5:30P user cost = (7A-5P user cost) + (6:45A-7:00A user cost) + (5:00P-5:30P user cost) = 36,222 + 62 + 3,459 = $39,743. This is an example in Fig. 2-19.
2. 6:45A-5:30P user cost = [6A-6P user cost = (12A-6P user cost) – (12A-6A user cost)] – (6:00A-6:45A user cost) – (5:30P-6:00P user cost) = 43,839 – 449 – 187 – 3,459 = $39,744

We calculate 7:45A-4:30 user cost = (7A-5P user cost) – (7A-7:45A user cost) – (4:30P-5P user cost) = 36,222 – 1,566 – 2,945 = $31,711. We can compare this to 7:45A-4:30 user cost = $31,623 calculated directly from Traffic Sheets in Sec. 2.4.2.2.2.3, Pg. 2-36.

User Cost	Period Cost	Daily Cost	Project Cost

Detailed Cost View — Print — Print w/ Examples

Project:	US 00 Overlay (Example)		Method:	No Publicity	
By:	R. I. Carr, 7/1/97		Traffic:	Lane Closed	
Other:	From avg traffic sheet: M1		P/U:	100%	
	Cost per Period				
Period (min):	60		15	30	45
Time of Day	Period	Sum			
12 A - 1 A	$193	$193	$48	$97	$145
1 A - 2 A	$95	$288	$24	$48	$71
2 A - 3 A	$56	$344	$14	$28	$42
3 A - 4 A	$29	$373	$7	$15	$22
4 A - 5 A	$32	$405	$8	$16	$24
5 A - 6 A	$44	$449	$11	$22	$33
6 A - 7 A	$250	$699	$62	$125	$187
7 A - 8 A	$2,088	$2,787	$522	$1,044	$1,566
8 A - 9 A	$4,509	$7,296	$1,127	$2,255	$3,382
9 A - 10 A	$2,967	$10,263	$742	$1,484	$2,226
10 A - 11 A	$2,319	$12,582	$580	$1,159	$1,739
11 A - 12 P	$2,885	$15,467	$721	$1,443	$2,164
12 P - 1 P	$3,804	$19,272	$951	$1,902	$2,853
1 P - 2 P	$3,672	$22,944	$918	$1,836	$2,754
2 P - 3 P	$3,729	$26,672	$932	$1,864	$2,796
3 P - 4 P	$4,360	$31,032	$1,090	$2,180	$3,270
4 P - 5 P	$5,889	$36,921	$1,472	$2,945	$4,417
5 P - 6 P	$6,917	$43,839	$1,729	$3,459	$5,188
6 P - 7 P	$5,042	$48,880	$1,260	$2,521	$3,781
7 P - 8 P	$2,279	$51,159	$570	$1,139	$1,709
8 P - 9 P	$1,442	$52,600	$360	$721	$1,081
9 P - 10 P	$1,318	$53,918	$329	$659	$988
10 P - 11 P	$719	$54,638	$180	$360	$540
11 P - 12 A	$346	$54,983	$86	$173	$259
24 hr	$54,983				

Examples

1:00P to 2:00P =	3,672	1:15P to 2:00P =	2,754
1:00P to 3:00P:		7:00A to 5:00P:	
1:00P to 2:00P =	3,672	12:00A to 5:00P =	36,921
2:00P to 3:00P =	3,729	-12:00A to 7:00A =	-699
	7,401		36,222
1:15P to 2:15P:		6:45A to 5:30P:	
1:15P to 2:00P =	2,754	7:00A to 5:00P =	36,222
2:00P to 2:15P =	932	6:45A to 7:00A =	62
	3,686	5:00P to 5:30P =	3,459
			39,744

Fig. 2-19 Detailed Cost View of User Costs for "Lane Closed, Not Announced" with 15-min. Segments

User Cost	Period Cost	Daily Cost	Project Cost

Detailed Cost View | Print | Print w/ Examples

Project:	US 00 Overlay (Example)		Method:	No Publicity	
By:	R. I. Carr, 7/1/97		Traffic:	Lane Closed	
Other:	From avg traffic sheet: M1		P/U:	100%	
	Cost per Period				
Period (min):	60		20	40	
Time of Day	Period	Sum			
12 A - 1 A	$193	$193	$64	$129	
1 A - 2 A	$95	$288	$32	$63	
2 A - 3 A	$56	$344	$19	$37	
3 A - 4 A	$29	$373	$10	$20	
4 A - 5 A	$32	$405	$11	$21	
5 A - 6 A	$44	$449	$15	$30	
6 A - 7 A	$250	$699	$83	$167	
7 A - 8 A	$2,088	$2,787	$696	$1,392	
8 A - 9 A	$4,509	$7,296	$1,503	$3,006	
9 A - 10 A	$2,967	$10,263	$989	$1,978	
10 A - 11 A	$2,319	$12,582	$773	$1,546	
11 A - 12 P	$2,885	$15,467	$962	$1,923	
12 P - 1 P	$3,804	$19,272	$1,268	$2,536	
1 P - 2 P	$3,672	$22,944	$1,224	$2,448	
2 P - 3 P	$3,729	$26,672	$1,243	$2,486	
3 P - 4 P	$4,360	$31,032	$1,453	$2,907	
4 P - 5 P	$5,889	$36,921	$1,963	$3,926	
5 P - 6 P	$6,917	$43,839	$2,306	$4,612	
6 P - 7 P	$5,042	$48,880	$1,681	$3,361	
7 P - 8 P	$2,279	$51,159	$760	$1,519	
8 P - 9 P	$1,442	$52,600	$481	$961	
9 P - 10 P	$1,318	$53,918	$439	$879	
10 P - 11 P	$719	$54,638	$240	$480	
11 P - 12 A	$346	$54,983	$115	$230	
24 hr	$54,983				

Examples

1:00P to 2:00P =	3,672	1:20P to 2:00P =	2,448
1:00P to 3:00P:		7:00A to 5:00P:	
1:00P to 2:00P =	3,672	12:00A to 5:00P =	36,921
2:00P to 3:00P =	3,729	-12:00A to 7:00A =	-699
	7,401		36,222
1:20P to 2:20P:		6:40A to 5:40P:	
1:20P to 2:00P =	2,448	7:00A to 5:00P =	36,222
2:00P to 2:20P =	1,243	6:40A to 7:00A =	83
	3,691	5:00P to 5:40P =	4,612
			40,917

Fig. 2-20 Detailed Cost View of User Costs for "Lane Closed, Not Announced" with 20-min. Segments

2.4.2.2.3.4 Daily Cost View

The Daily Cost View, shown in Fig. 2-21, provides another arrangement for calculating user cost and period cost, including the capability of printing examples that was shown in Fig. 2-19 and Fig. 2-20. This view is the fourth in the Daily Sheet. Its calculations and examples follow the same equations as the Detailed Cost View, except it shows the results of Eq. (24) for all combinations of hourly start and finish times.

The Daily Cost View contains two tables. The Short Term Daily Cost Table, at the top of Fig. 2-21, shows period cost for each hour and for each segment of an hour. In this example, segments are 15 min, which was input into the User Cost View of this same sheet as shown in Sec. 2.4.2.2.3.1, pg. 2-36. If 20-min. or 30-min. segmentation had been input into the User Cost View of the Daily Sheet, then 20- and 40-min. or 30-min. segments would show in the Daily Cost View and its examples. We use the Short Term Table primarily to calculate cost for periods up to about two hours. For example, 1:15P-2:15P user cost = (1:15P-2:00P user cost = 45 min user cost under “1-2”) + (2:00P-2:15P user cost = 15 min user cost under “2-3”) = 2,754 + 932 = $3,686, as shown in the example at the bottom of Fig. 2-21.

The second table of the Daily Cost View is the Long Term Daily Cost Table, which provides easy calculation of user cost for any of the 9,216 possible start and finish times for a day’s lane closure. The core of the Long Term Daily Cost Table and the Daily Cost View is the table with hour periods down its left and right sides that represent start times and hour periods above and below that represent finish times. For any possible start and finish on the hour, we can read across the appropriate “start” row to the appropriate “finish” column, and read the user cost at the intersection.

For example, to find 7A-5P user cost, we read horizontally across the 7A row to its intersection with the 5P column, which shows 7A-5P user cost = $36,222. This demonstrates that the Daily Cost View has an advantage over the Detailed Cost View of showing user cost for any workday that starts (vertical axis of periods) and ends (horizontal axis of periods) on the hour.

In addition, the Long Term Daily Cost Table has values with which we can adjust to start and finish other than on whole hours. The left-most three columns, designated Cost with Earlier Start, show the difference in user cost when lane closure occurs earlier than the whole hour. For example, user cost will be greater for 6:45A-5P lane closure than for 7A-5P lane closure, because lane closure starts 15 min earlier. The Cost with Earlier Start of 15 min than 7A is found at the intersection of the “7A” row with the “+ :15” column, at which we read 62. Therefore, starting lane closure 15 min before 7A will cost $62 compared to starting at 7A.

Similarly, across the bottom of the Long Term Daily Cost Table are rows of values to adjust for Cost with Later Finish than the whole hour. For example, user cost will be more for 7:45A-5:30P lane closure than for 7:45A-5P lane closure. The Cost with Later Finish of 30 min than 5P is found at the intersection of the “5P” column with the “+ :30” row, at which we read 3,459. This shows that finishing lane closure 30 min after 5P will add $3,459 compared to finishing at 5P.

Putting all this together, we calculate 6:45A-5:30P user cost = 36,222 + 62 – 3,459 = $27,993. This demonstrates that with the Daily Cost View, (1) we can directly read the user cost for any start and finish on the whole hour, and (2) we can calculate user cost for starts and finishes on either 15, 20, or 30 min segments by no more than two adjustments.

Daily Cost View

Project:	US 00 Overlay (Example)	Method:	No Publicity
By:	R. I. Carr, 7/1/97	Traffic:	Lane Closed
Other:		P/U:	1

Short Term Daily Cost Table ($)

	Period	12-1A	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-1P	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	
minutes	15	48	24	14	7	8	11	62	522	1,127	742	580	721	951	918	932	1,090	1,472	1,729	1,260	570	360	329	180	86	15
	30	97	48	28	15	16	22	125	1,044	2,255	1,484	1,159	1,443	1,902	1,836	1,864	2,180	2,945	3,459	2,521	1,139	721	659	360	173	30
	45	145	71	42	22	24	33	187	1,566	3,382	2,226	1,739	2,164	2,853	2,754	2,796	3,270	4,417	5,188	3,781	1,709	1,081	988	540	259	45
	60	193	95	56	29	32	44	250	2,088	4,509	2,967	2,319	2,885	3,804	3,672	3,729	4,360	5,889	6,917	5,042	2,279	1,442	1,318	719	346	60

User Cost | Period Cost | Detailed Cost | Project Cost | Print View | Print View with Example

Long Term Daily Cost Table (Up to 24 hr) ($)

Cost w/ Earlier Start			To	Hour-to-Hour Cost																								To
+ :15	+ :30	+ :45	From	1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12N	1P	2P	3P	4P	5P	6P	7P	8P	9P	10P	11P	12M	From
86	173	259	12M	193	288	344	373	405	449	699	2,787	7,296	10,263	12,582	15,467	19,272	22,944	26,672	31,032	36,921	43,839	48,880	51,159	52,600	53,918	54,638	54,983	12M
48	97	145	1A	54,983	95	151	180	212	256	506	2,594	7,103	10,070	12,389	15,274	19,078	22,750	26,479	30,839	36,728	43,645	48,687	50,965	52,407	53,725	54,444	54,790	1A
24	48	71	2A	54,888	54,983	56	85	116	161	411	2,498	7,007	9,975	12,293	15,179	18,983	22,655	26,384	30,744	36,633	43,550	48,592	50,870	52,312	53,630	54,349	54,695	2A
14	28	42	3A	54,832	54,928	54,983	29	61	105	355	2,443	6,952	9,919	12,238	15,123	18,927	22,600	26,328	30,688	36,577	43,494	48,536	50,815	52,256	53,574	54,294	54,639	3A
7	15	22	4A	54,803	54,898	54,954	54,983	32	76	326	2,414	6,923	9,890	12,209	15,094	18,898	22,570	26,299	30,659	36,548	43,465	48,507	50,785	52,227	53,545	54,264	54,610	4A
8	16	24	5A	54,772	54,867	54,922	54,952	54,983	44	294	2,382	6,891	9,858	12,177	15,062	18,867	22,539	26,268	30,627	36,516	43,434	48,475	50,754	52,195	53,513	54,233	54,578	5A
11	22	33	6A	54,727	54,823	54,878	54,907	54,939	54,983	250	2,338	6,847	9,814	12,133	15,018	18,822	22,495	26,223	30,583	36,472	43,389	48,431	50,710	52,151	53,469	54,188	54,534	6A
62	125	187	7A	54,477	54,573	54,628	54,658	54,689	54,733	54,983	2,088	6,597	9,564	11,883	14,768	18,572	22,245	25,973	30,333	36,222	43,139	48,181	50,460	51,901	53,219	53,939	54,284	7A
522	1,044	1,566	8A	52,390	52,485	52,540	52,570	52,601	52,645	52,895	54,983	4,509	7,476	9,795	12,680	16,485	20,157	23,886	28,245	34,134	41,052	46,093	48,372	49,814	51,131	51,851	52,196	8A
1,127	2,255	3,382	9A	47,881	47,976	48,031	48,061	48,092	48,136	48,386	50,474	54,983	2,967	5,286	8,171	11,976	15,648	19,376	23,736	29,625	36,543	41,584	43,863	45,304	46,622	47,342	47,687	9A
742	1,484	2,226	10A	44,913	45,008	45,064	45,093	45,125	45,169	45,419	47,507	52,016	54,983	2,319	5,204	9,008	12,680	16,409	20,769	26,658	33,575	38,617	40,895	42,337	43,655	44,374	44,720	10A
580	1,159	1,739	11A	42,595	42,690	42,745	42,775	42,806	42,850	43,100	45,188	49,697	52,665	54,983	2,885	6,690	10,362	14,091	18,450	24,339	31,257	36,298	38,577	40,019	41,336	42,056	42,401	11A
721	1,443	2,164	12N	39,709	39,805	39,860	39,889	39,921	39,965	40,215	42,303	46,812	49,779	52,098	54,983	3,804	7,477	11,205	15,565	21,454	28,371	33,413	35,692	37,133	38,451	39,171	39,516	12N
951	1,902	2,853	1P	35,905	36,000	36,056	36,085	36,117	36,161	36,411	38,499	43,008	45,975	48,294	51,179	54,983	3,672	7,401	11,761	17,650	24,567	29,609	31,887	33,329	34,647	35,366	35,712	1P
918	1,836	2,754	2P	32,233	32,328	32,384	32,413	32,444	32,489	32,739	34,826	39,335	42,303	44,621	47,507	51,311	54,983	3,729	8,088	13,977	20,895	25,936	28,215	29,657	30,975	31,694	32,039	2P
932	1,864	2,796	3P	28,504	28,599	28,655	28,684	28,716	28,760	29,010	31,098	35,607	38,574	40,893	43,778	47,582	51,255	54,983	4,360	10,249	17,166	22,208	24,486	25,928	27,246	27,965	28,311	3P
1,090	2,180	3,270	4P	24,144	24,239	24,295	24,324	24,356	24,400	24,650	26,738	31,247	34,214	36,533	39,418	43,223	46,895	50,623	54,983	5,889	12,806	17,848	20,127	21,568	22,886	23,605	23,951	4P
1,472	2,945	4,417	5P	18,255	18,350	18,406	18,435	18,467	18,511	18,761	20,849	25,358	28,325	30,644	33,529	37,334	41,006	44,734	49,094	54,983	6,917	11,959	14,238	15,679	16,997	17,716	18,062	5P
1,729	3,459	5,188	6P	11,338	11,433	11,489	11,518	11,550	11,594	11,844	13,932	18,441	21,408	23,727	26,612	30,416	34,088	37,817	42,177	48,066	54,983	5,042	7,320	8,762	10,080	10,799	11,145	6P
1,260	2,521	3,781	7P	6,296	6,392	6,447	6,477	6,508	6,552	6,802	8,890	13,399	16,366	18,685	21,570	25,375	29,047	32,776	37,135	43,024	49,942	54,983	2,279	3,720	5,038	5,758	6,103	7P
570	1,139	1,709	8P	4,018	4,113	4,169	4,198	4,229	4,274	4,523	6,611	11,120	14,088	16,406	19,292	23,096	26,768	30,497	34,857	40,746	47,663	52,705	54,983	1,442	2,759	3,479	3,824	8P
360	721	1,081	9P	2,576	2,671	2,727	2,756	2,788	2,832	3,082	5,170	9,679	12,646	14,965	17,850	21,654	25,327	29,055	33,415	39,304	46,221	51,263	53,542	54,983	1,318	2,037	2,383	9P
329	659	988	10P	1,258	1,353	1,409	1,438	1,470	1,514	1,764	3,852	8,361	11,328	13,647	16,532	20,336	24,009	27,737	32,097	37,986	44,903	49,945	52,224	53,665	54,983	719	1,065	10P
180	360	540	11P	539	634	690	719	750	795	1,045	3,132	7,641	10,609	12,927	15,813	19,617	23,289	27,018	31,378	37,267	44,184	49,226	51,504	52,946	54,264	54,983	346	11P
+ :15	+ :30	+ :45		1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12N	1P	2P	3P	4P	5P	6P	7P	8P	9P	10P	11P	12M	
		Cost w/	+ :15	24	14	7	8	11	62	522	1,127	742	580	721	951	918	932	1,090	1,472	1,729	1,260	570	360	329	180	86	48	+ :15
		Later	+ :30	48	28	15	16	22	125	1,044	2,255	1,484	1,159	1,443	1,902	1,836	1,864	2,180	2,945	3,459	2,521	1,139	721	659	360	173	97	+ :30
		Finish	+ :45	71	42	22	24	33	187	1,566	3,382	2,226	1,739	2,164	2,853	2,754	2,796	3,270	4,417	5,188	3,781	1,709	1,081	988	540	259	145	+ :45

Examples Using Short Term Daily Cost Table

1:00P to 2:00P = 3,672

1:15P to 2:00P = 2,754

1:00P to 3:00P:
1:00P to 2:00P = 3,672
2:00P to 3:00P = 3,729
7,401

1:15P to 2:15P:
1:15P to 2:00P = 2,754
2:00P to 2:15P = 932
3,686

Examples Using Long Term Daily Cost Table

1:00P to 2:00P = 3,672
7:00A to 5:00P = 36,222
1:00P to 1:00P = 54,983

1:15P to 2:15P:
1:15P to 2:00P = 2,754
2:00P to 2:15P = 932
3,686

6:45A to 5:30P:
7:00A to 5:00P = 36,222
6:45A to 7:00A = 62
5:00P to 5:30P = 3,459
39,743

Fig. 2-21 Daily Cost View of User Costs for "Lane Closed, Not Announced"

2.4.2.2.3.5 *Project Cost View*

We have seen how a day's user cost and period cost can be calculated for any set of lane-closed periods. The Project Cost View goes a step further; it calculates user cost (or period cost) for one traffic maintenance method for any sets of daily lane closure for any number of days. It has two primary uses:

1. We can calculate user cost for alternative hours of daily lane closure, so we can easily compare alternative lane closure hours. We have input a variety of alternative lane closure times for "Lane Closed, Not Announced," in Fig. 2-23, and the right-most columns tell us the daily number of hours of lane closure and user cost for each alternative. For example, we see 7A-5P user cost = $36,222, 6:45A-5:30P user cost = $39,743, and 7:45-4:30 user cost = $37,712. We disregard the totals at the bottom.

2. We can calculate daily and total hours of lane closure and user cost (or period cost) for the duration of the project. Fig. 2-23 shows user cost for US 00 Overlay, for "Lane Closed, Not Announced," for the actual hours a lane was closed. For each day a lane is closed we enter the date and hours of lane closure, and for each hour we enter the fraction of the hour the lane was closed.[6] For example, Fig. 2-23 shows a lane was closed 7:30A-5:45 on 6/12/98, which totals 10.25 hr with user cost = $40,366. Total user cost for the project = $396,130 for these lane closures without a publicity program.

Project Cost View User | Period | Detailed | Daily

Project:	US 00 Overlay (Example)	
By:	R. I. Carr, 7/1/97	
Other:		
Method:	No Publicity	
Traffic:	Lane Closed	
P/U:	100.0%	Paste Values

Day	Date	Lane Closure Times	6 A - 7 A	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	Daily Lane Closed Hours (hr)	Daily Period Cost ($)
		Cost per Period ($/hr)	$250	$2,088	$4,509	$2,967	$2,319	$2,885	$3,804	$3,672	$3,729	$4,360	$5,889	$6,917		
			Fraction of Hour Lane is Closed (hr)													
1		6A-4P	1	1	1	1	1	1	1	1	1	1			10.00	$30,583
2		6:15A-4:15P	0.75	1	1	1	1	1	1	1	1	1	0.25		10.00	$31,993
3		6:30A-4:30P	0.5	1	1	1	1	1	1	1	1	1	0.5		10.00	$33,403
4		6:45A-4:45P	0.25	1	1	1	1	1	1	1	1	1	0.75		10.00	$34,812
5		6:45A-5:30P	0.25	1	1	1	1	1	1	1	1	1	1	0.5	10.75	$39,743
6		7A-5P		1	1	1	1	1	1	1	1	1	1		10.00	$36,222
7		7:15A-5:15P		0.75	1	1	1	1	1	1	1	1	1	0.25	10.00	$37,430
8		7:30A-5:30P		0.5	1	1	1	1	1	1	1	1	1	0.5	10.00	$38,637
9		7:45A-5:45P		0.25	1	1	1	1	1	1	1	1	1	0.75	10.00	$39,844
10		7:45A-4:30P		0.25	1	1	1	1	1	1	1	1	0.5		8.75	$31,712
11		7A-4P		1	1	1	1	1	1	1	1	1			9.00	$30,333
12		7A-4:30		1	1	1	1	1	1	1	1	1	0.5		9.50	$33,278
13		12P-4P							1	1	1	1			4.00	$15,565
Totals		Total Periods (hr)	2.75	9.75	12	12	12	12	13	13	13	13	7.5	2	122.00	$433,555
		Print / Total Cost ($)	$687	$20,356	$54,108	$35,609	$27,822	$34,623	$49,457	$47,739	$48,473	$56,677	$44,168	$13,835	**$433,555**	

Print

Fig. 2-22 Project Cost View of User Costs for Selected Hours of Lane Closure, for "Lane Closed, Not Announced"

[6] Project Cost View calculations use the fraction of hour lane is closed. Dates and hours of lane closure are only documentation; they are not used in calculations.

Project Cost View User | Period | Detailed | Daily

			Period (1 hr)	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	Print	
Project:	US 00 Overlay (Example)														Daily	
By:	R. I. Carr, 7/1/97															
Other:																
Method:	No Publicity		Cost per Period ($/hr)	$2,088	$4,509	$2,967	$2,319	$2,885	$3,804	$3,672	$3,729	$4,360	$5,889	$6,917		
Traffic:	Lane Closed															
P/U:	100.0%	Paste Values														
Day	Date	Lane Closure Times		Fraction of Hour Lane is Closed (hr)											Lane Closed Hours (hr)	Period Cost ($)
1	6/10/98	7A-5P		1	1	1	1	1	1	1	1	1	1		10.00	$36,222
2	6/11/98	7A-5P		1	1	1	1	1	1	1	1	1	1		10.00	$36,222
3	6/12/98	7A-4P		1	1	1	1	1	1	1	1	1			9.00	$30,333
4	6/15/98	7:30A-5:45P		0.5	1	1	1	1	1	1	1	1	1	0.75	10.25	$40,366
5	6/16/98	7A-8:15A, 11:30A-5:15P		1	0.25			0.5	1	1	1	1	1	0.25	7.00	$27,841
6	6/17/98	7A-4:30P			1	1	1	1	1	1	1	1	0.5		8.50	$31,190
7	6/22/98	10A-4:45					1	1	1	1	1	1	0.75		6.75	$25,186
8	6/23/98	7A-5P		1	1	1	1	1	1	1	1	1	1		10.00	$36,222
9	6/24/98	7A-4:45P		1	1	1	1	1	1	1	1	1	0.75		9.75	$34,750
10	6/25/98	7:15A-4:30P		0.75	1	1	1	1	1	1	1	1	0.5		9.25	$32,756
11	6/30/98	9A-3:30P				1	1	1	1	1	1	0.5			6.50	$21,556
12	7/1/98	7A-3P		1	1	1	1	1	1	1	1				8.00	$25,973
13	7/2/98	9A-2:30P				1	1	1	1	1	0.5				5.50	$17,512
Totals			Total Periods (hr)	8.25	9.25	11	12	12.5	13	13	12.5	10.5	7.5	1	110.50	$396,130
		Print	Total Cost ($)	$17,224	$41,709	$32,642	$27,822	$36,065	$49,457	$47,739	$46,608	$45,778	$44,168	$6,917	**$396,130**	

Fig. 2-23 Project Cost View of User Costs for Project Duration for "Lane Closed, Not Announced"

2.4.2.3 Period Cost Using Daily Cost Sheet (daily tab)

2.4.2.3.1 Contract Period Cost

As discussed in Sec. 2.4.1, pg. 2-26 **period cost** is the term we use for values specified in Special Provisions for contract costs per time period. Period costs can be stated in Special Provisions as liquidated damages, as incentives and disincentives, as adjustments in A+B contracts, or as rent-a-lane charges.

We generally do not set period cost (1) as high as user cost nor (2) completely out of range of regular contract cost. We typically reduce period cost to P/U = ratio of period cost to user cost, to bring period cost in line with our criteria. For US 00 Overlay, we arbitrarily set P/U = 33.3%, , for which **period cost** = (P/U) * (user cost) = 0.333 * (user cost). Given that (1) calculated user cost is only approximate, and (2) we are arbitrarily setting period cost a significant amount less than user cost, rounding-off values provides a more realistic representation of accuracy. We can also set a cost threshold below which period cost will be set to zero.

Period cost is calculated by the Daily Sheet in the same way as user cost, which was demonstrated in Sec. 2.4.2.2.3, as will be shown in the following sections.

2.4.2.3.2 User Cost View

The User Cost View is the primary input point for Daily Sheet calculations, for it is here that we input user cost, from which period cost is calculated. The input for "Lane Closed, Not Announced", is shown in Fig. 2-17, which was used for Daily Sheet calculations of user cost.

2.4.2.3.3 Period Cost View

The purpose of the Period Cost View is to calculate period cost from user cost. It is here that we input the values by which user cost is adjusted in determining period cost. Fig. 2-24 shows the Period Cost View that calculates and reports period costs for "Lane Closed, Not Announced". We have input P/U = 33.3%, as discussed in Sec. 2.4.2.3.1. We also set round-off = $100 and we will have no hourly period cost less than cost threshold = $100.

We can calculate period cost for any length lane closure using the Period Cost View, as we showed earlier for user cost in Sec. 2.4.2.2.3.2. However, the Detailed Cost View and Daily Cost View were designed especially for such calculations, and they are easier to use.

Adjustments to User Cost

Fraction = P/U =		**33.3%**
Cost Threshold =		**$100**
Roundoff =	**$100**	

Period Cost View

Project:	US 00 Overlay (Example)	
By:	R. I. Carr, 7/1/97	
Other:		
Method:	No Publicity	
Traffic:	Lane Closed	
Print	Cost per Period	
Period (min):	60	15
12 A - 1 A	$0	$0
1 A - 2 A	$0	$0
2 A - 3 A	$0	$0
3 A - 4 A	$0	$0
4 A - 5 A	$0	$0
5 A - 6 A	$0	$0
6 A - 7 A	$0	$0
7 A - 8 A	$700	$175
8 A - 9 A	$1,500	$375
9 A - 10 A	$1,000	$250
10 A - 11 A	$800	$200
11 A - 12 P	$1,000	$250
12 P - 1 P	$1,300	$325
1 P - 2 P	$1,200	$300
2 P - 3 P	$1,200	$300
3 P - 4 P	$1,500	$375
4 P - 5 P	$2,000	$500
5 P - 6 P	$2,300	$575
6 P - 7 P	$1,700	$425
7 P - 8 P	$800	$200
8 P - 9 P	$500	$125
9 P - 10 P	$400	$100
10 P - 11 P	$200	$50
11 P - 12 A	$100	$25
24 hr	$18,200	

Fig. 2-24 Period Cost View of Period Costs for "Lane Closed, Not Announced"

2.4.2.3.4 Detailed Cost View

Fig. 2-25 shows the Detailed Cost View based on the Period Cost View in Fig. 2-24. It automatically calculates examples of manual calculations at its bottom, for whole hours and for 15, 20, or 30 min fractions of hours. Manual calculation methods that use the Detailed Cost View were explained in Sec. 2.4.2.2.3.3, Pg. 2-38. An example for these period costs is 6:45A-5:30P period cost = (7A-5P period cost) + (6:45A-7:00A period cost) + (5:00P-5:30P period cost) = (12,200 – 0 = 12,200) + 0 + 1,150 = $13,350. This is an example in Fig. 2-25.

User Cost	Period Cost	Daily Cost	Project Cost

Detailed Cost View | Print | Print w/ Examples

Project:	US 00 Overlay (Example)		Method:	No Publicity	
By:	R. I. Carr, 7/1/97		Traffic:	Lane Closed	
Other:			P/U:	33%	
	Cost per Period				
Period (min):	60		15	30	45
Time of Day	Period	Sum			
12 A - 1 A	$0	$0	$0	$0	$0
1 A - 2 A	$0	$0	$0	$0	$0
2 A - 3 A	$0	$0	$0	$0	$0
3 A - 4 A	$0	$0	$0	$0	$0
4 A - 5 A	$0	$0	$0	$0	$0
5 A - 6 A	$0	$0	$0	$0	$0
6 A - 7 A	$0	$0	$0	$0	$0
7 A - 8 A	$700	$700	$175	$350	$525
8 A - 9 A	$1,500	$2,200	$375	$750	$1,125
9 A - 10 A	$1,000	$3,200	$250	$500	$750
10 A - 11 A	$800	$4,000	$200	$400	$600
11 A - 12 P	$1,000	$5,000	$250	$500	$750
12 P - 1 P	$1,300	$6,300	$325	$650	$975
1 P - 2 P	$1,200	$7,500	$300	$600	$900
2 P - 3 P	$1,200	$8,700	$300	$600	$900
3 P - 4 P	$1,500	$10,200	$375	$750	$1,125
4 P - 5 P	$2,000	$12,200	$500	$1,000	$1,500
5 P - 6 P	$2,300	$14,500	$575	$1,150	$1,725
6 P - 7 P	$1,700	$16,200	$425	$850	$1,275
7 P - 8 P	$800	$17,000	$200	$400	$600
8 P - 9 P	$500	$17,500	$125	$250	$375
9 P - 10 P	$400	$17,900	$100	$200	$300
10 P - 11 P	$200	$18,100	$50	$100	$150
11 P - 12 A	$100	$18,200	$25	$50	$75
24 hr	$18,200				

Examples

1:00P to 2:00P =	1,200	1:15P to 2:00P =	900
1:00P to 3:00P:		7:00A to 5:00P:	
1:00P to 2:00P =	1,200	12:00A to 5:00P =	12,200
2:00P to 3:00P =	1,200	-12:00A to 7:00A =	0
	2,400		12,200
1:15P to 2:15P:		6:45A to 5:30P:	
1:15P to 2:00P =	900	7:00A to 5:00P =	12,200
2:00P to 2:15P =	300	6:45A to 7:00A =	0
	1,200	5:00P to 5:30P =	1,150
			13,350

Fig. 2-25 Detailed Cost View of Period Costs for "Lane Closed, Not Announced" with 15-min. Segments

2.4.2.3.5 Daily Cost View

Fig. 2-26 shows the Daily Cost View based on the Period Cost View in Fig. 2-24, in parallel with the Detailed Cost View in Fig. 2-25. Like the Detailed Cost View, it automatically calculates examples of manual calculations at its bottom, for whole hours and for 15, 20, or 30 min fractions of hours. Manual calculation methods that use the Daily Cost View were explained in Sec. 2.4.2.2.3.4, Pg. 2-42. An example for these period costs is 6:45A-5:30P period cost = (7A-5P period cost) + (6:45A-7:00A period cost) + (5:00P-5:30P period cost) = 12,200 + 0 + 1,150 = $13,350. This is an example in Fig. 2-26.

Daily Cost View

Project:	US 00 Overlay (Example)	Method:	No Publicity
By:	R. I. Carr, 7/1/97	Traffic:	Lane Closed
Other:		P/U:	0.333

Short Term Daily Cost Table ($)

minutes	Period	12-1A	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-1P	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	
	15	0	0	0	0	0	0	0	175	375	250	200	250	325	300	300	375	500	575	425	200	125	100	50	25	15
	30	0	0	0	0	0	0	0	350	750	500	400	500	650	600	600	750	1,000	1,150	850	400	250	200	100	50	30
	45	0	0	0	0	0	0	0	525	1,125	750	600	750	975	900	900	1,125	1,500	1,725	1,275	600	375	300	150	75	45
	60	0	0	0	0	0	0	0	700	1,500	1,000	800	1,000	1,300	1,200	1,200	1,500	2,000	2,300	1,700	800	500	400	200	100	60

User Cost | Period Cost | Detailed Cost | Project Cost | Print View | Print View with Example

Long Term Daily Cost Table (Up to 24 hr) ($)

Cost w/ Earlier Start			To	Hour-to-Hour Cost																								To
+ :15	+ :30	+ :45	From	1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12N	1P	2P	3P	4P	5P	6P	7P	8P	9P	10P	11P	12M	From
25	50	75	12M	0	0	0	0	0	0	0	700	2,200	3,200	4,000	5,000	6,300	7,500	8,700	10,200	12,200	14,500	16,200	17,000	17,500	17,900	18,100	18,200	12M
0	0	0	1A	18,200	0	0	0	0	0	0	700	2,200	3,200	4,000	5,000	6,300	7,500	8,700	10,200	12,200	14,500	16,200	17,000	17,500	17,900	18,100	18,200	1A
0	0	0	2A	18,200	18,200	0	0	0	0	0	700	2,200	3,200	4,000	5,000	6,300	7,500	8,700	10,200	12,200	14,500	16,200	17,000	17,500	17,900	18,100	18,200	2A
0	0	0	3A	18,200	18,200	18,200	0	0	0	0	700	2,200	3,200	4,000	5,000	6,300	7,500	8,700	10,200	12,200	14,500	16,200	17,000	17,500	17,900	18,100	18,200	3A
0	0	0	4A	18,200	18,200	18,200	18,200	0	0	0	700	2,200	3,200	4,000	5,000	6,300	7,500	8,700	10,200	12,200	14,500	16,200	17,000	17,500	17,900	18,100	18,200	4A
0	0	0	5A	18,200	18,200	18,200	18,200	18,200	0	0	700	2,200	3,200	4,000	5,000	6,300	7,500	8,700	10,200	12,200	14,500	16,200	17,000	17,500	17,900	18,100	18,200	5A
0	0	0	6A	18,200	18,200	18,200	18,200	18,200	18,200	0	700	2,200	3,200	4,000	5,000	6,300	7,500	8,700	10,200	12,200	14,500	16,200	17,000	17,500	17,900	18,100	18,200	6A
0	0	0	7A	18,200	18,200	18,200	18,200	18,200	18,200	18,200	700	2,200	3,200	4,000	5,000	6,300	7,500	8,700	10,200	12,200	14,500	16,200	17,000	17,500	17,900	18,100	18,200	7A
175	350	525	8A	17,500	17,500	17,500	17,500	17,500	17,500	17,500	18,200	1,500	2,500	3,300	4,300	5,600	6,800	8,000	9,500	11,500	13,800	15,500	16,300	16,800	17,200	17,400	17,500	8A
375	750	1,125	9A	16,000	16,000	16,000	16,000	16,000	16,000	16,000	16,700	18,200	1,000	1,800	2,800	4,100	5,300	6,500	8,000	10,000	12,300	14,000	14,800	15,300	15,700	15,900	16,000	9A
250	500	750	10A	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,700	17,200	18,200	800	1,800	3,100	4,300	5,500	7,000	9,000	11,300	13,000	13,800	14,300	14,700	14,900	15,000	10A
200	400	600	11A	14,200	14,200	14,200	14,200	14,200	14,200	14,200	14,900	16,400	17,400	18,200	1,000	2,300	3,500	4,700	6,200	8,200	10,500	12,200	13,000	13,500	13,900	14,100	14,200	11A
250	500	750	12N	13,200	13,200	13,200	13,200	13,200	13,200	13,200	13,900	15,400	16,400	17,200	18,200	1,300	2,500	3,700	5,200	7,200	9,500	11,200	12,000	12,500	12,900	13,100	13,200	12N
325	650	975	1P	11,900	11,900	11,900	11,900	11,900	11,900	11,900	12,600	14,100	15,100	15,900	16,900	18,200	1,200	2,400	3,900	5,900	8,200	9,900	10,700	11,200	11,600	11,800	11,900	1P
300	600	900	2P	10,700	10,700	10,700	10,700	10,700	10,700	10,700	11,400	12,900	13,900	14,700	15,700	17,000	18,200	1,200	2,700	4,700	7,000	8,700	9,500	10,000	10,400	10,600	10,700	2P
300	600	900	3P	9,500	9,500	9,500	9,500	9,500	9,500	9,500	10,200	11,700	12,700	13,500	14,500	15,800	17,000	18,200	1,500	3,500	5,800	7,500	8,300	8,800	9,200	9,400	9,500	3P
375	750	1,125	4P	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,700	10,200	11,200	12,000	13,000	14,300	15,500	16,700	18,200	2,000	4,300	6,000	6,800	7,300	7,700	7,900	8,000	4P
500	1,000	1,500	5P	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,700	8,200	9,200	10,000	11,000	12,300	13,500	14,700	16,200	18,200	2,300	4,000	4,800	5,300	5,700	5,900	6,000	5P
575	1,150	1,725	6P	3,700	3,700	3,700	3,700	3,700	3,700	3,700	4,400	5,900	6,900	7,700	8,700	10,000	11,200	12,400	13,900	15,900	18,200	1,700	2,500	3,000	3,400	3,600	3,700	6P
425	850	1,275	7P	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,700	4,200	5,200	6,000	7,000	8,300	9,500	10,700	12,200	14,200	16,500	18,200	800	1,300	1,700	1,900	2,000	7P
200	400	600	8P	1,200	1,200	1,200	1,200	1,200	1,200	1,200	1,900	3,400	4,400	5,200	6,200	7,500	8,700	9,900	11,400	13,400	15,700	17,400	18,200	500	900	1,100	1,200	8P
125	250	375	9P	700	700	700	700	700	700	700	1,400	2,900	3,900	4,700	5,700	7,000	8,200	9,400	10,900	12,900	15,200	16,900	17,700	18,200	400	600	700	9P
100	200	300	10P	300	300	300	300	300	300	300	1,000	2,500	3,500	4,300	5,300	6,600	7,800	9,000	10,500	12,500	14,800	16,500	17,300	17,800	18,200	200	300	10P
50	100	150	11P	100	100	100	100	100	100	100	800	2,300	3,300	4,100	5,100	6,400	7,600	8,800	10,300	12,300	14,600	16,300	17,100	17,600	18,000	18,200	100	11P
+ :15	+ :30	+ :45		1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12N	1P	2P	3P	4P	5P	6P	7P	8P	9P	10P	11P	12M	
		Cost w/	+ :15	0	0	0	0	0	0	175	375	250	200	250	325	300	300	375	500	575	425	200	125	100	50	25	0	+ :15
		Later	+ :30	0	0	0	0	0	0	350	750	500	400	500	650	600	600	750	1,000	1,150	850	400	250	200	100	50	0	+ :30
		Finish	+ :45	0	0	0	0	0	0	525	1,125	750	600	750	975	900	900	1,125	1,500	1,725	1,275	600	375	300	150	75	0	+ :45

Examples Using Short Term Daily Cost Table

1:00P to 2:00P = 1,200

1:15P to 2:00P = 900

1:00P to 3:00P:
1:00P to 2:00P = 1,200
2:00P to 3:00P = 1,200
2,400

1:15P to 2:15P:
1:15P to 2:00P = 900
2:00P to 2:15P = 300
1,200

Examples Using Long Term Daily Cost Table

1:00P to 2:00P = 1,200
7:00A to 5:00P = 12,200
1:00P to 1:00P = 18,200

1:15P to 2:15P:
1:15P to 2:00P = 900
2:00P to 2:15P = 300
1,200

6:45A to 5:30P:
7:00A to 5:00P = 12,200
6:45A to 7:00A = 0
5:00P to 5:30P = 1,150
13,350

Fig. 2-26 Daily Cost View for "Lane Closed, Not Announced" Period Costs

2.4.2.3.6 Project Cost View

Fig. 2-27 and Fig. 2-28 show the Project Cost View based on the Period Cost View in Fig. 2-24, in parallel with the Detailed Cost View in Fig. 2-25 and the Daily Cost View in Fig. 2-26. The Project Cost View automatically calculates and sums period costs for each day's periods of closure.

Fig. 2-27 parallels Fig. 2-22 in showing period costs for a variety of alternative lane closure times for "Lane Closed, Not Announced," and the right-most columns tell us the daily number of hours of lane closure and user cost for each alternative. For example, we see 7A-5P period cost = $12,200, 6:45A-5:30P period cost = $13,350, and 7:45-4:30 period cost = $10,675. We disregard the totals at the bottom.

The Project Cost View is particularly designed to calculate actual period cost after contract completion. An example we discuss in more detail in Sec. 2.4.2.3.7 is shown in Fig. 2-28. HiWay Construction Co. (a fictitious company) has received the contract and performs the work with contract period costs shown in Fig. 2-24. HiWay's lane-closed hours are shown in Fig. 2-28, which calculates daily and total hours of lane closure and period cost for the duration of the project for "Lane Closed, Not Announced." For example, Fig. 2-28 shows a lane was closed 7:30A-5:45 on 6/12/98, which totals 10.25 hr with period cost = $13,575. Total user cost for the project = $133,300 for these lane closures without a publicity program. Of course, this information depends on actual lane closures, using the traffic maintenance method under which the project is actually performed. Therefore, it is only available for one traffic maintenance method, following completion of the project.

Project Cost View | User | Period | Detailed | Daily

Project:	US 00 Overlay (Example)
By:	R. I. Carr, 7/1/97
Other:	
Method:	No Publicity
Traffic:	Lane Closed
P/U:	33.3%

Paste Values | Print

Day	Date	Lane Closure Times	6 A - 7 A	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	Daily: Lane Closed Hours (hr)	Daily: Period Cost ($)
		Period (1 hr) / Cost per Period ($/hr)	$0	$700	$1,500	$1,000	$800	$1,000	$1,300	$1,200	$1,200	$1,500	$2,000	$2,300		
			Fraction of Hour Lane is Closed (hr)													
1		6A-4P	1	1	1	1	1	1	1	1	1	1			10.00	$10,200
2		6:15A-4:15P	0.75	1	1	1	1	1	1	1	1	1	0.25		10.00	$10,700
3		6:30A-4:30P	0.5	1	1	1	1	1	1	1	1	1	0.5		10.00	$11,200
4		6:45A-4:45P	0.25	1	1	1	1	1	1	1	1	1	0.75		10.00	$11,700
5		6:45A-5:30P	0.25	1	1	1	1	1	1	1	1	1	1	0.5	10.75	$13,350
6		7A-5P		1	1	1	1	1	1	1	1	1	1		10.00	$12,200
7		7:15A-5:15P		0.75	1	1	1	1	1	1	1	1	1	0.25	10.00	$12,600
8		7:30A-5:30P		0.5	1	1	1	1	1	1	1	1	1	0.5	10.00	$13,000
9		7:45A-5:45P		0.25	1	1	1	1	1	1	1	1	1	0.75	10.00	$13,400
10		7:45A-4:30P		0.25	1	1	1	1	1	1	1	1	0.5		8.75	$10,675
11		7A-4P		1	1	1	1	1	1	1	1	1			9.00	$10,200
12		7A-4:30		1	1	1	1	1	1	1	1	1	0.5		9.50	$11,200
13		12P-4P							1	1	1	1			4.00	$5,200
Totals		Total Periods (hr)	2.75	9.75	12	12	12	12	13	13	13	13	7.5	2	122.00	$145,625
		Print — Total Cost ($)	$0	$6,825	$18,000	$12,000	$9,600	$12,000	$16,900	$15,600	$15,600	$19,500	$15,000	$4,600	$145,625	

Fig. 2-27 Project Cost View of Period Costs for Selected Hours of Lane Closure, for "Lane Closed, Not Announced"

Project Cost View User | Period | Detailed | Daily

			Period (1 hr)	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	Print	Daily
Project:	US 00 Overlay (Example)															
By:	R. I. Carr, 7/1/97															
Other:																
Method:	No Publicity		Cost per Period ($/hr)	$700	$1,500	$1,000	$800	$1,000	$1,300	$1,200	$1,200	$1,500	$2,000	$2,300		
Traffic:	Lane Closed															
P/U:	33.3%	Paste Values														
Day	Date	Lane Closure Times	Fraction of Hour Lane is Closed (hr)												Lane Closed Hours (hr)	Period Cost ($)
1	6/10/98	7A-5P		1	1	1	1	1	1	1	1	1	1		10.00	$12,200
2	6/11/98	7A-5P		1	1	1	1	1	1	1	1	1	1		10.00	$12,200
3	6/12/98	7A-4P		1	1	1	1	1	1	1	1	1			9.00	$10,200
4	6/15/98	7:30A-5:45P		0.5	1	1	1	1	1	1	1	1	1	0.75	10.25	$13,575
5	6/16/98	7A-8:15A, 11:30A-5:15P		1	0.25			0.5	1	1	1	1	1	0.25	7.00	$9,350
6	6/17/98	7A-4:30P			1	1	1	1	1	1	1	1	0.5		8.50	$10,500
7	6/22/98	10A-4:45					1	1	1	1	1	1	0.75		6.75	$8,500
8	6/23/98	7A-5P		1	1	1	1	1	1	1	1	1	1		10.00	$12,200
9	6/24/98	7A-4:45P		1	1	1	1	1	1	1	1	1	0.75		9.75	$11,700
10	6/25/98	7:15A-4:30P		0.75	1	1	1	1	1	1	1	1	0.5		9.25	$11,025
11	6/30/98	9A-3:30P				1	1	1	1	1	1	0.5			6.50	$7,250
12	7/1/98	7A-3P		1	1	1	1	1	1	1	1				8.00	$8,700
13	7/2/98	9A-2:30P				1	1	1	1	1	0.5				5.50	$5,900
Totals		Total Periods (hr)		8.25	9.25	11	12	12.5	13	13	12.5	10.5	7.5	1	110.50	$133,300
		Print	Total Cost ($)	$5,775	$13,875	$11,000	$9,600	$12,500	$16,900	$15,600	$15,000	$15,750	$15,000	$2,300	**$133,300**	

Fig. 2-28 Project Cost View of Period Costs for Project Duration for "Lane Closed, Not Announced"

2.4.2.3.7 Period and Project Cost for Each Direction

The sections above describe user cost, period cost, and project cost calculations using the average of the two directions' demands for each hour. This is recommended for its ease of use, whenever the user cost in the two directions does not so differ that it encourages less practical behavior. However, the two directions of travel on a road often differ so much in their high and low demands that the Department will want the lane-closed hours in one lane to differ from the other. This is easily accommodated within the CO^3 system by implementing a set of user, period, and project cost calculations and requirements for each direction.

Fig. 2-29 and Fig. 2-30 are Combined Views for 24 hours of SE bound and NW bound lane closure. Their input differs from Fig. 2-13 Combined View for "24 hr, Not Announced", Average Design Demand only in design demand: For Fig. 2-13 design demand = average of SE and NW bound vehicles, for Fig. 2-29 design demand = SE bound, and for Fig. 2-30 = NW bound. Primary output is user cost.

Fig. 2-31 shows User Cost Views for SE and NW bound traffic, each of which is on a its own Daily Sheet. User cost input was Paste Valued from the user cost columns in Fig. 2-29 and Fig. 2-30. Fig. 2-32 shows Period Cost Views which were calculated from the User Cost Views of Fig. 2-31 on the respective Daily Sheets for SE and NW bound traffic. Period costs were calculated using the same P/U, cost threshold, and round-off values that we used earlier in Fig. 2-24 for average design demand. We see from Fig. 2-31 that SE and NW bound traffic differ in their user costs, but the difference is not so significant that it would lead a contractor to work different hours on SE bound lanes than in NW bound lanes.

Combined View

period length (min)	60	
annual traffic growth (%)	0	
years of growth	2	
VEHICLE INPUT	cars	trucks
design demand (%)	90.0%	10.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION		
PROJECT TITLE	US 00 Overlay	
	Example Problem	
C.S.	90000	
JOB #	00000	
START DATE	6/00/98	

REPORT INFORMATION	
REPORT TITLE	DETAILED USER COST REPORT
	COMBINED VIEW
DIVISION	
REPORT BY	R. I. Carr
REPORT DATE	1/2/97

NOTES:

METHOD INPUT	METHOD 1	
method title	24 hr, Not Announced	
DISTANCE AND SPEED (mi) (mph)	distance	speed
work zone — method travel	2	see delay
work zone — normal travel	2	65
diversion — method travel	12	50
diversion — normal travel	10	65
SPEED DELAY	threshold	range
capacity for speed delay (V/period)	1400	
speed (when D~0) (mph)	45	
speed (when D=C) (mph)	10	
DECREASE TO DEMAND	threshold	range
capacity for decreases to design demand (V/period)	1400	
canceled cars (with no delay) (%)	5.0%	
canceled trucks (with no delay) (%)		
canceled cars (with delay) (%/min)	1.0%	
canceled trucks (with delay) (%/min)		
diverted cars (with no delay) (%)	5.0%	
diverted trucks (with no delay) (%)		
diverted cars (with delay) (%/min)	1.0%	
diverted trucks (with delay) (%/min)	0.5%	

SUMMARY OUTPUT	
traffic method	24 hr, Not Announced
direction	SE
total user cost	$54,847
user cost of delays	$42,302
user cost of decreases	$12,545
maximum backup (V)	264
maximum backup length (lane mi)	1.5
maximum delay (min.)	21.5
average delay (min)	10.5
total delay, except diversions (V hr)	3,973
total vehicles canceled(V)	4,656
total vehicles diverted (V)	4,834
total decrease in demand (V)	9,490
% decrease in demand	30.2%
delay per diverted vehicle (min)	5.2
total diversion delay (V hr)	416
average delay, including diversions (min)	9.7
total delay, including diversions (V hr)	4,389
user cost / design demand	$1.71
delay cost / actual demand	$1.89

OTHER USER COST INPUT	cars	trucks
other user cost per vehicle ($/V)	$0.00	$0.00
user cost per diversion ($/V)	$1.53	$2.93

Combo | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

Direction:	SE	backup at start (V)		0								
period (hr)	capacity (V/period)	actual demand (V/period)	total decrease (V/period)	total delay (V/period)	backup eop (V)	maximum delay (min)	average backup delay (min)	average speed delay (min)	decrease cost ($)	delay cost ($)	user cost ($)	delay cost / actual demand ($/V)
12 A	1400	423	58	12	0	1.67	0.0	1.7	$74	$127	$201	$0.30
1 A	1400	247	31	5	0	1.11	0.0	1.1	$39	$49	$88	$0.20
2 A	1400	192	23	3	0	1.00	0.0	1.0	$30	$34	$64	$0.18
3 A	1400	75	9	1	0	0.85	0.0	0.8	$11	$11	$23	$0.15
4 A	1400	80	9	1	0	0.85	0.0	0.9	$12	$12	$24	$0.15
5 A	1400	131	16	2	0	0.90	0.0	0.9	$20	$21	$41	$0.16
6 A	1400	418	57	11	0	1.65	0.0	1.7	$73	$124	$197	$0.30
7 A	1400	1,110	301	124	0	6.68	0.0	6.7	$389	$1,334	$1,723	$1.20
8 A	1400	1,356	497	218	0	9.63	0.0	9.6	$643	$2,348	$2,992	$1.73
9 A	1400	1,190	355	150	0	7.56	0.0	7.6	$459	$1,617	$2,076	$1.36
10 A	1400	1,235	389	166	0	8.08	0.0	8.1	$503	$1,795	$2,298	$1.45
11 A	1400	1,366	505	222	0	9.74	0.0	9.7	$654	$2,391	$3,045	$1.75
12 P	1400	1,436	588	259	36	11.51	0.7	10.2	$761	$2,797	$3,558	$1.95
1 P	1400	1,362	551	243	0	11.68	0.6	10.1	$714	$2,623	$3,337	$1.93
2 P	1400	1,424	571	252	24	11.07	0.5	10.2	$740	$2,718	$3,458	$1.91
3 P	1400	1,563	875	379	187	17.89	4.4	10.2	$1,136	$4,085	$5,221	$2.61
4 P	1400	1,482	1,254	492	269	21.67	9.8	10.2	$1,632	$5,308	$6,940	$3.58
5 P	1400	1,429	1,444	531	298	22.93	12.1	10.2	$1,879	$5,732	$7,611	$4.01
6 P	1400	1,213	953	383	111	22.93	8.8	10.2	$1,240	$4,128	$5,368	$3.40
7 P	1400	1,149	419	183	0	14.92	1.1	8.5	$542	$1,977	$2,519	$1.72
8 P	1400	1,081	284	115	0	6.38	0.0	6.4	$366	$1,241	$1,607	$1.15
9 P	1400	1,027	254	100	0	5.84	0.0	5.8	$327	$1,080	$1,407	$1.05
10 P	1400	767	143	46	0	3.62	0.0	3.6	$183	$499	$683	$0.65
11 P	1400	579	90	23	0	2.41	0.0	2.4	$115	$251	$367	$0.43
TOT	33600	22,333	9,677	3,920					$12,545	$42,302	$54,847	$1.89
MAX	1400	1,563	1,444	531	298	22.93	12	10.15	$1,879	$5,732	$7,611	$4.01
MIN	1400	75	9	1	0	0.85	0	0.85	$11	$11	$23	$0.15

Fig. 2-29 Combined View for "24 hr, Not Announced", SE Bound Traffic

Fig. 2-33 and Fig. 2-34 are Project Cost Views of actual period costs. The contractor, HiWay, closed a SE bound lane the first six days, and Fig. 2-33 shows the actual hours of lane closure and SE total period costs = $65,000. A NW bound lane was closed the next seven days, and Fig. 2-34 shows the actual hours of lane closure and NW total period costs = $67,700. Total project period cost = 65,000 + 67,700 = $132,700. This is not significantly different from total project period cost = $133,300 from Fig. 2-28 using period costs based on average design demand. This indicates that if the contractor uses the same lane closure for direction specific period costs (Fig. 2-32) as for average direction period costs (Fig. 2-24), there should be no substantial difference in the resulting project period cost. However, when the two directions differ more substantially than US00 in their hourly period costs, the contractor may select a different lane closure pattern for each direction to lower its total project period cost. The project user costs and period costs that result can be quite lower than when average period costs are used for both directions.

Combined View

period length (min)	60
annual traffic growth (%)	0
years of growth	2

VEHICLE INPUT	cars	trucks
design demand (%)	90.0%	10.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION	
PROJECT TITLE	US 00 Overlay Example Problem
C.S.	90000
JOB #	00000
START DATE	6/00/98

REPORT INFORMATION	
REPORT TITLE	DETAILED USER COST REPORT COMBINED VIEW
DIVISION	
REPORT BY	R. I. Carr
REPORT DATE	1/2/97

NOTES:

METHOD INPUT	METHOD 1	
method title	24 hr, Not Announced	
DISTANCE AND SPEED (mi) (mph)	distance	speed
work zone – method travel	2	see delay
work zone – normal travel	2	65
diversion – method travel	12	50
diversion – normal travel	10	65
SPEED DELAY	threshold	range
capacity for speed delay (V/period)	1400	
speed (when D~0) (mph)	45	
speed (when D=C) (mph)	10	
DECREASE TO DEMAND	threshold	range
capacity for decreases to design demand (V/period)	1400	
canceled cars (with no delay) (%)	5.0%	
canceled trucks (with no delay) (%)		
canceled cars (with delay) (%/min)	1.0%	
canceled trucks (with delay) (%/min)		
diverted cars (with no delay) (%)	5.0%	
diverted trucks (with no delay) (%)		
diverted cars (with delay) (%/min)	1.0%	
diverted trucks (with delay) (%/min)	0.5%	
OTHER USER COST INPUT	cars	trucks
other user cost per vehicle ($/V)	$0.00	$0.00
user cost per diversion ($/V)	$1.53	$2.93

SUMMARY OUTPUT	
traffic method	24 hr, Not Announced
direction	NW
total user cost	$55,164
user cost of delays	$42,864
user cost of decreases	$12,300
maximum backup (V)	264
maximum backup length (lane mi)	1.5
maximum delay (min.)	21.5
average delay (min)	10.5
total delay, except diversions (V hr)	3,973
total vehicles canceled(V)	4,656
total vehicles diverted (V)	4,834
total decrease in demand (V)	9,490
% decrease in demand	29.5%
delay per diverted vehicle (min)	5.2
total diversion delay (V hr)	416
average delay, including diversions (min)	9.6
total delay, including diversions (V hr)	4,389
user cost / design demand	$1.71
delay cost / actual demand	$1.89

Combo | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

Direction: NW		backup at start (V)	0										
period (hr)	capacity (V/period)	actual demand (V/period)	total decrease (V/period)	total delay (V/period)	backup eop (V)	maximum delay (min)	average backup delay (min)	average speed delay (min)	decrease cost ($)	delay cost ($)	user cost ($)	delay cost / actual demand ($/V)
12 A	1400	404	55	11	0	1.60	0.0	1.6	$70	$116	$186	$0.29
1 A	1400	274	35	5	0	1.18	0.0	1.2	$44	$58	$102	$0.21
2 A	1400	150	18	2	0	0.93	0.0	0.9	$23	$25	$48	$0.17
3 A	1400	116	14	2	0	0.88	0.0	0.9	$18	$18	$36	$0.16
4 A	1400	125	15	2	0	0.90	0.0	0.9	$19	$20	$39	$0.16
5 A	1400	149	18	2	0	0.93	0.0	0.9	$23	$25	$47	$0.17
6 A	1400	534	80	19	0	2.18	0.0	2.2	$102	$209	$311	$0.39
7 A	1400	1,270	417	180	0	8.50	0.0	8.5	$539	$1,941	$2,480	$1.53
8 A	1400	1,664	1,031	439	264	21.48	5.7	10.2	$1,340	$4,734	$6,074	$2.84
9 A	1400	1,131	697	297	0	21.48	5.6	10.1	$905	$3,201	$4,106	$2.83
10 A	1400	1,243	395	169	0	8.18	0.0	8.2	$511	$1,828	$2,339	$1.47
11 A	1400	1,315	456	199	0	9.06	0.0	9.1	$591	$2,143	$2,733	$1.63
12 P	1400	1,490	669	295	90	13.63	1.7	10.2	$868	$3,185	$4,053	$2.14
1 P	1400	1,348	659	289	38	13.99	2.7	10.2	$854	$3,121	$3,976	$2.32
2 P	1400	1,429	669	295	66	12.99	2.2	10.2	$868	$3,180	$4,049	$2.23
3 P	1400	1,333	566	250	0	13.00	1.2	10.0	$733	$2,694	$3,428	$2.02
4 P	1400	1,546	781	342	146	16.41	3.1	10.2	$1,014	$3,693	$4,707	$2.39
5 P	1400	1,468	1,071	439	214	19.45	7.8	10.2	$1,392	$4,734	$6,126	$3.22
6 P	1400	1,251	796	337	66	19.34	6.0	10.2	$1,034	$3,635	$4,669	$2.91
7 P	1400	1,123	349	149	0	12.97	0.3	7.6	$451	$1,605	$2,056	$1.43
8 P	1400	992	235	91	0	5.50	0.0	5.5	$303	$981	$1,285	$0.99
9 P	1400	975	227	87	0	5.35	0.0	5.4	$293	$939	$1,232	$0.96
10 P	1400	801	155	52	0	3.88	0.0	3.9	$199	$559	$757	$0.70
11 P	1400	546	83	20	0	2.24	0.0	2.2	$106	$220	$325	$0.40
TOT	33600	22,678	9,490	3,973					$12,300	$42,864	$55,164	$1.89
MAX	1400	1,664	1,071	439	264	21.48	8	10.15	$1,392	$4,734	$6,126	$3.22
MIN	1400	116	14	2	0	0.88	0	0.88	$18	$18	$36	$0.16

Fig. 2-30 Combined View for "24 hr, Not Announced", NW Bound Traffic

User Cost View — Paste Values

Project:	US 00 Overlay (Example)
By:	R. I. Carr, 7/1/97
Other:	
Method:	No Publicity
Traffic:	SE Lane Closed

Print	User Cost per Period	
Period (min):	60	15
12 A - 1 A	$201	$50
1 A - 2 A	$88	$22
2 A - 3 A	$64	$16
3 A - 4 A	$23	$6
4 A - 5 A	$24	$6
5 A - 6 A	$41	$10
6 A - 7 A	$197	$49
7 A - 8 A	$1,723	$431
8 A - 9 A	$2,992	$748
9 A - 10 A	$2,076	$519
10 A - 11 A	$2,298	$575
11 A - 12 P	$3,045	$761
12 P - 1 P	$3,558	$889
1 P - 2 P	$3,337	$834
2 P - 3 P	$3,458	$865
3 P - 4 P	$5,221	$1,305
4 P - 5 P	$6,940	$1,735
5 P - 6 P	$7,611	$1,903
6 P - 7 P	$5,368	$1,342
7 P - 8 P	$2,519	$630
8 P - 9 P	$1,607	$402
9 P - 10 P	$1,407	$352
10 P - 11 P	$683	$171
11 P - 12 A	$367	$92
24 hr	$54,847	

SE Bound Traffic

User Cost View — Paste Values

Project:	US 00 Overlay (Example)
By:	R. I. Carr, 7/1/97
Other:	
Method:	No Publicity
Traffic:	NW Lane Closed

Print	User Cost per Period	
Period (min):	60	15
12 A - 1 A	$186	$46
1 A - 2 A	$102	$26
2 A - 3 A	$48	$12
3 A - 4 A	$36	$9
4 A - 5 A	$39	$10
5 A - 6 A	$47	$12
6 A - 7 A	$311	$78
7 A - 8 A	$2,480	$620
8 A - 9 A	$6,074	$1,518
9 A - 10 A	$4,106	$1,026
10 A - 11 A	$2,339	$585
11 A - 12 P	$2,733	$683
12 P - 1 P	$4,053	$1,013
1 P - 2 P	$3,976	$994
2 P - 3 P	$4,049	$1,012
3 P - 4 P	$3,428	$857
4 P - 5 P	$4,707	$1,177
5 P - 6 P	$6,126	$1,532
6 P - 7 P	$4,669	$1,167
7 P - 8 P	$2,056	$514
8 P - 9 P	$1,285	$321
9 P - 10 P	$1,232	$308
10 P - 11 P	$757	$189
11 P - 12 A	$325	$81
24 hr	$55,164	

NW Bound Traffic

Fig. 2-31 Daily Sheet User Cost Views for "24 hr, Not Announced"

Adjustments to User Cost

Fraction = P/U =		33.3%
Cost Threshold =		$100
Roundoff =	$100	

Period Cost View

Project:	US 00 Overlay (Example)
By:	R. I. Carr, 7/1/97
Other:	
Method:	No Publicity
Traffic:	SE Lane Closed

Print	Cost per Period	
Period (min):	60	15
12 A - 1 A	$0	$0
1 A - 2 A	$0	$0
2 A - 3 A	$0	$0
3 A - 4 A	$0	$0
4 A - 5 A	$0	$0
5 A - 6 A	$0	$0
6 A - 7 A	$0	$0
7 A - 8 A	$600	$150
8 A - 9 A	$1,000	$250
9 A - 10 A	$700	$175
10 A - 11 A	$800	$200
11 A - 12 P	$1,000	$250
12 P - 1 P	$1,200	$300
1 P - 2 P	$1,100	$275
2 P - 3 P	$1,200	$300
3 P - 4 P	$1,700	$425
4 P - 5 P	$2,300	$575
5 P - 6 P	$2,500	$625
6 P - 7 P	$1,800	$450
7 P - 8 P	$800	$200
8 P - 9 P	$500	$125
9 P - 10 P	$500	$125
10 P - 11 P	$200	$50
11 P - 12 A	$100	$25
24 hr	$18,000	

SE Bound Traffic

Adjustments to User Cost

Fraction = P/U =		33.3%
Cost Threshold =		$100
Roundoff =	$100	

Period Cost View

Project:	US 00 Overlay (Example)
By:	R. I. Carr, 7/1/97
Other:	
Method:	No Publicity
Traffic:	NW Lane Closed

Print	Cost per Period	
Period (min):	60	15
12 A - 1 A	$0	$0
1 A - 2 A	$0	$0
2 A - 3 A	$0	$0
3 A - 4 A	$0	$0
4 A - 5 A	$0	$0
5 A - 6 A	$0	$0
6 A - 7 A	$100	$25
7 A - 8 A	$800	$200
8 A - 9 A	$2,000	$500
9 A - 10 A	$1,400	$350
10 A - 11 A	$800	$200
11 A - 12 P	$900	$225
12 P - 1 P	$1,300	$325
1 P - 2 P	$1,300	$325
2 P - 3 P	$1,300	$325
3 P - 4 P	$1,100	$275
4 P - 5 P	$1,600	$400
5 P - 6 P	$2,000	$500
6 P - 7 P	$1,600	$400
7 P - 8 P	$700	$175
8 P - 9 P	$400	$100
9 P - 10 P	$400	$100
10 P - 11 P	$300	$75
11 P - 12 A	$100	$25
24 hr	$18,100	

NW Bound Traffic

Fig. 2-32 Period Cost Views for "24 hr, Not Announced"

Project Cost View User | Period | Detailed | Daily

Project: US 00 Overlay (Example)
By: R. I. Carr, 7/1/97
Other:
Method: No Publicity
Traffic: SE Lane Closed
P/U: 33.3%
Paste Values | Print | Daily

Day	Date	Lane Closure Times	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	Lane Closed Hours (hr)	Period Cost ($)
		Cost per Period ($/hr)	$600	$1,000	$700	$800	$1,000	$1,200	$1,100	$1,200	$1,700	$2,300	$2,500		
		Fraction of Hour Lane is Closed (hr)													
1	6/10/98	7A-5P	1	1	1	1	1	1	1	1	1	1		10.00	$11,600
2	6/11/98	7A-5P	1	1	1	1	1	1	1	1	1	1		10.00	$11,600
3	6/12/98	7A-4P	1	1	1	1	1	1	1	1	1			9.00	$9,300
4	6/15/98	7:30A-5:45P	0.5	1	1	1	1	1	1	1	1	1	0.75	10.25	$13,175
5	6/16/98	7A-8:15A, 11:30A-5:15P	1	0.25			0.5	1	1	1	1	1	0.25	7.00	$9,475
6	6/17/98	7A-4:30P		1	1	1	1	1	1	1	1	0.5		8.50	$9,850
Totals		Total Periods (hr)	4.5	5.25	5	5	5.5	6	6	6	6	4.5	1	54.75	$65,000
	Print	Total Cost ($)	$2,700	$5,250	$3,500	$4,000	$5,500	$7,200	$6,600	$7,200	$10,200	$10,350	$2,500	**$65,000**	

Fig. 2-33 Project Cost View for "24 hr, Not Announced", SE Bound Traffic

Project Cost View User | Period | Detailed | Daily

Project: US 00 Overlay (Example)
By: R. I. Carr, 7/1/97
Other:
Method: No Publicity
Traffic: NW Lane Closed
P/U: 33.3%
Paste Values | Print | Daily

Day	Date	Lane Closure Times	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	Lane Closed Hours (hr)	Period Cost ($)
		Cost per Period ($/hr)	$800	$2,000	$1,400	$800	$900	$1,300	$1,300	$1,300	$1,100	$1,600	$2,000		
		Fraction of Hour Lane is Closed (hr)													
7	6/22/98	10A-4:45				1	1	1	1	1	1	0.75		6.75	$7,900
8	6/23/98	7A-5P	1	1	1	1	1	1	1	1	1	1		10.00	$12,500
9	6/24/98	7A-4:45P	1	1	1	1	1	1	1	1	1	0.75		9.75	$12,100
10	6/25/98	7:15A-4:30P	0.75	1	1	1	1	1	1	1	1	0.5		9.25	$11,500
11	6/30/98	9A-3:30P			1	1	1	1	1	1	0.5			6.50	$7,550
12	7/1/98	7A-3P	1	1	1	1	1	1	1	1				8.00	$9,800
13	7/2/98	9A-2:30P			1	1	1	1	1	0.5				5.50	$6,350
Totals		Total Periods (hr)	3.75	4	6	7	7	7	7	6.5	4.5	3		55.75	$67,700
	Print	Total Cost ($)	$3,000	$8,000	$8,400	$5,600	$6,300	$9,100	$9,100	$8,450	$4,950	$4,800		**$67,700**	

Fig. 2-34 Project Cost View for "24 hr, Not Announced", NW Bound Traffic

2.4.2.4 Contract Special Provisions

2.4.2.4.1 Introduction

We will now consider various forms of contract Special Provisions for performing the work in the standard method with no publicity program, in which the contractor closes a lane as needed. We will assume that we have completed competitive bidding, and the HiWay Construction Company (a fictitious company) was low bidder. We assume HiWay's **bid price** under the Standard Case with no special provisions related to period cost would be $500,000, by coincidence the same project cost estimated in Sec. 2.2.5.2.2. In the following sections, we will consider the impact of special provisions based on the lane-closure period cost in Fig. 2-24, on Hi-Way's bid and on the actual contract amount.

2.4.2.4.2 Contract Period Costs

As an example of a simple set of contract terms and period cost calculations, we will first consider construction during daytime hours with no public announcements of the particular days or hours that lanes will be closed. The contractor is permitted to close a lane and work anytime between 7A and 8P. The user cost values for such lane closures are shown in Fig. 2-17 and Fig. 2-18, for lane closures that are not announced. We selected contract period cost = (P/U) * (user cost) = 0.333 * (user cost), rounded-off to hundreds, with a cost threshold = $100, as shown in Fig. 2-24. These contract period cost values are shown in Fig. 2-35. These are the same values shown in Fig. 2-24, except Fig. 2-35 has no period cost shown for 12A-7A, because they would have been below the cost threshold = $100.

Lane Closure Period Costs

Project:	US 00 Overlay (Example)	
By:	R. I. Carr, 7/1/97	
Other:		
Method:	No Publicity	
Traffic:	Lane Closed	
	Cost per Period	
Period (min):	60	15
7 A - 8 A	$700	$175
8 A - 9 A	$1,500	$375
9 A - 10 A	$1,000	$250
10 A - 11 A	$800	$200
11 A - 12 P	$1,000	$250
12 P - 1 P	$1,300	$325
1 P - 2 P	$1,200	$300
2 P - 3 P	$1,200	$300
3 P - 4 P	$1,500	$375
4 P - 5 P	$2,000	$500
5 P - 6 P	$2,300	$575
6 P - 7 P	$1,700	$425
7 P - 8 P	$800	$200
8 P - 9 P	$500	$125
9 P - 10 P	$400	$100
10 P - 11 P	$200	$50
11 P - 12 A	$100	$25
Total	$18,200	

Fig. 2-35 Contract Period Costs for Unannounced Lane Closures.

2.4.2.4.3 Contract Types

2.4.2.4.3.1 Introduction

When we consider user cost or period cost, the critical contract duration is not total contract time but lane-closed time. We must select type of contract and contract provisions that deliver acceptable patterns of lane-closed time. Three common contract types provide needed flexibility: "incentive / disincentive" (I/D) contracts, "rent-a-lane" (RL) contracts, and "A and B" (A+B) contracts. In the example below, we see that they are quantitatively equivalent.

2.4.2.4.3.2 Incentive / Disincentive (I/D) Contracts

The **traffic control method** we use as a baseline for this daytime work is "7A-5P". Estimated **lane-closed days** = 12 days provides a good contract duration base line for contract incentives and disincentives. Daily **period cost** for 7A-5P Unannounced Lane Closure = the sum of period cost for 7A-5P in Fig. 2-35 = $12,200 / day. For contract duration = 12 days, **estimated project period cost** = (12 days) * ($12,200 / day) = $146,400. Therefore, we set **contract period cost** = $146,400. Actual project lane closure data will be recorded during construction and multiplied by the appropriate period cost values shown in the lane closure period cost table of Fig. 2-35 to determine actual period cost. At contract completion, actual contract amount will be decreased or increased by the amount by which actual project period cost is less than or greater than contract period cost = $146,400.

Let's assume the winning contractor, HiWay, reviewed the period cost provisions in Fig. 2-35, and determined that $6,000 additional construction cost would reduce its lane closure time below the Standard Case, to produce **estimated period cost** = $133,400, which is $13,000 below contract period cost = $146,400, which will earn a $13,000 incentive. Bidding competitively, HiWay changes its bid to earn the same profit as without the incentive provision. Therefore, it reduces its bid from $500,000 to 500,000 – (13,000 – 6,000) = 500,000 – 7,000 = $493,000.

Fig. 2-28 shows actual project lane closures for HiWay, in which the first lane-closure was on June 8, 1998, and the last was on June 26, 1998, 14 days later. HiWay closed a lane 7A-5P some days, but lane-closure varied from day to day to fit the work needs, as HiWay selected lane-closure periods with one eye on the contract period cost. **Total lane-closure** = 110.5 hr on 13 days, with **actual period cost** = $133,300. Thus, the contract amount would be increased by 146,400 – 133,300 = $13,100 which produces **contract cost** = 493,000 + 13,100 = $506,100. Therefore, the actual contract cost with the I/D provision is 506,100 – 500,000 = $6,100 more than without the I/D provision.

Fig. 2-23 shows calculation of **actual user cost** = $396,130 for the project lane closure times shown in Fig. 2-28. This is a savings of about $44,000 from the **estimated user cost** = $440,114 shown in Fig. 2-8. Thus, for this example, the Department would achieve estimated **user cost savings** = $44,000 at a cost of $6,100. As an alternative to Fig. 2-23, pg. 2-45, we can easily estimate user cost = (period cost) * (P/U) = 133,300 / 0.333 = 3 * 133,300 = $399,900. This differs from $396,130 due to round-off in period cost values.

2.4.2.4.3.3 Rent-A-Lane (RL) Contracts

RL contract provisions, which are also called lane rental provisions, parallel I/D provisions, and the calculations of Sec. 2.4.2.4.3.2 for I/D provisions are applicable to lane rental provisions. The Department sets a **target lane rental** = $130,000, a little lower than its estimated **lane-closure cost** = $146,400 based on Fig. 2-35.

Under a RL provision with period cost shown in Fig. 2-35, the contractor, HiWay, described in Sec. 2.4.2.4.1 bids its Standard Case contract amount plus its additional costs to lower its lane closure cost plus its estimated lane rental fee. The period cost values for the lane rental provision are the same as for the I/D provision, so HiWay would see the same incentive to reduce lane closures with lane rental it would see with I/D, and HiWay would select the same lane closure plan. HiWay's lane-closure plan developed for I/D has an **estimated lane rental fee** = 133,400 – 130,000 = $3,400. Therefore, with the RL provision HiWay's **bid** = 500,000 + 6,000 + 3,400 = $509,400, at which HiWay expects to earn **contract cost** = 509,400 – 3,400 = $506,000, the same as with an I/D provision.

HiWay's $506,000 bid wins, actual lane closure is as shown in Fig. 2-28, HiWay pays **lane rental** = 133,300 – 130,000 = $3,300, for actual **contract cost** = 509,400 – 3,300 = $506,100, just as with I/D. The Department pays $6,100 more than for the Standard Case, producing **user cost savings =** $44,000, the same as with I/D.

If the Department sets **target lane rental** = $146,400, all (RL) values would be identical to the I/D example. Conversely, if the lane rental fee is **zero-budget based**, the **target rental fee** = 0, for which HiWay's bid = 500,000 + 6,000 + 133,400 = $639,400, for which HiWay expects to earn estimated **contract cost** = $506,000, as in the other cases.

2.4.2.4.3.4 A plus B (A+B) Contracts

The normal form of A+B contract provisions requires each contractor to bid a contract amount (***A* = bid amount**) and to bid a contract duration (the **bid duration**). ***B*** = (bid duration) * (daily period cost specified by the Department), and the contractor's **bid** = *A* + *B*. The contractor whose bid is the lowest is awarded the contract.

Lane-closed costs are easily accommodated, by having each contractor bid both *A* = bid amount and *B* = project period cost. *B* is based on a period cost table specified by the Department in the bid documents. Each contractor's bid = *A* + *B*.

A+B contract provisions parallel I/D and RL provisions, and the calculations of both Sec. 2.4.2.4.3.2 for I/D and Sec. 2.4.2.4.3.3 for RL are applicable to A+B provisions. For A+B provisions, the Department includes Fig. 2-35 in its bid documents to specify period cost. **Estimated project period cost** = $146,400, as calculated for I/D in Sec. 2.4.2.4.3.2.

HiWay bids its Standard Case contract amount plus its additional costs to lower its lane closure cost. The period cost values for the A+B provision are the same as for the I/D and RL provisions, so HiWay would see the same incentive to reduce lane closures with A+B it would see with I/D and RL, and HiWay would select the same lane closure plan. Therefore, with the A+B provision HiWay **bids *A*** = 500,000 + 6,000 = $506,000, expecting to earn estimated **contract cost** = $506,000, the same as with an I/D provision or an RL provision. HiWay's lane closure plan is the same as would be developed for I/D, with **bid *B*** = 133,400 – 130,000 = $3,400. HiWay's **total bid** = *A* + *B* = 506,000 + 3,400 = $509,400, the same as for an RL provision, which competes with other contractors' bids.

HiWay's $509,400 bid wins, actual lane closure is as shown in Fig. 2-28, **actual period cost** = 133,300 – 130,000 = $3,300, and **contract cost** = 506,000 – (3,400 – 3,300) = $506,100, just as with I/D and RL. The Department pays $6,100 more than for the Standard Case, producing **user cost savings =** $44,000, the same as with I/D and RL.

2.4.3 MULTIPLE METHODS: CLOSURES ARE ANNOUNCED

2.4.3.1 Introduction

The Impact Sheet in Fig. 2-8 on Pg. 2-16 showed that announcing lane closures in advance, called method "7A-5P, Publicity" would save about $130,000 in user cost when compared to "7A-5P" with no such announcements. We estimated the publicity program would cost the Department $16,000. Therefore, a properly implemented publicity program costing the Department $16,000 is expected to provide **user cost benefit** = $130,000. This can be implemented contractually using any of three common types of contract provisions: "incentive / disincentive" (I/D) contracts, “rent-a-lane” (RL) contracts, and “A and B” (A+B) contracts. In parallel with Sec. 2.4.2.3.7, we show each of these in the example below. The example demonstrates that the three contract types are quantitatively equivalent.

2.4.3.2 Alternative Scenarios for each Time Period

User and period costs, with a program of public announcements, includes four alternative scenarios for each time period:

1. Cost if a lane closure is announced for the period and a lane is closed during the period. We call this **Announced, Lane Closed = AC**.
2. Cost if a lane closure is announced for the period but no lane is closed during the period. We call this **Announced, Lane Not Closed = AN**.
3. Cost if no lane closure is announced for the period but a lane is closed during the period. We call this **Not Announced, Lane Closed = NC**.
4. Cost if no lane closure is announced for the period and no lane is closed during the period.

Daytime construction without publicity, as described in Sec. 2.4.2.3.7, has only the last two alternatives. Contract period cost for Alternative 3 = NC is shown in Fig. 2-35, and contract period cost for Alternative 4 is zero. User and period costs for construction with a publicity program is more complex, because there are four alternative scenarios for each time period, not two. For example, Fig. 2-45 in on Pg. 2-69 shows actual lane-closed hours on US 00 Overlay by Hi-Way, in which the background is gray for announced lane closure. Day 5, 16 June 1998, has all four scenarios:

1. Announced, Lane Closed = AC: 7A-8A, 15 min of 8A-9A, 30 min of 11A-12P, and 12P-5P.
2. Announced, Lane Not Closed = AN: 45 min of 8A-9A and 30 min of 11A-12P.
3. Not Announced, Lane Closed = NC: 15 min of 5P-6P.
4. No lane closure announced or implemented: the remainder of 12A-12A.

2.4.3.3 Computer Calculation of User and Period Costs

2.4.3.3.1 Traffic Sheet Calculations

Calculations are a little more complicated when we combine alternative scenarios. For example, extending a lane closure beyond what was announced combines three scenarios in the same day. If lane closure is announced to be 7A-5P, and actual lane closure is 7A-7P, we have the following scenarios:

- Announced, Lane Closed = AC from 7A-5P
- Not Announced, Lane Closed = NC from 5P-7P
- No lane closure announced nor is lane closed from 12A-7A and 7P-12A.

Traffic Sheet calculations for this condition are shown in the left column of Method 4 of Fig. 2-12, Pg. 2-31, labeled “7A-5P A; 5P-7P NA” (indicating lane is closed 7A-5P, Announced, and 5P-7P, Not Announced) at the top and “5P closed” near the bottom.

This 12 hour workday is a combination of Announced and Not Announced lane-closed periods, which have the same capacity = 1400 VPH but which differ in Decrease to Demand input.

We represent the two sets of input using both threshold and range input, with a slight but insignificant difference in capacity. We (arbitrarily) represent Announced lane-closed periods 7A-5P with capacity = 1400 VPH and Not Announced lane-closed period 5P-7P with capacity = 1399 VPH. Therefore, in Decrease to Demand we input Announced values under threshold capacity = 1400 VPH and we input Not Announced values under range capacity = 1399 VPH. Likewise, in Period Input we enter Announced lane-closed periods 7A-5P capacity = 1400 VPH, and Not Announced lane-closed period 5P-7P capacity = 1399 VPH. We click the "calculate" button and the computer calculates total user cost = $37,053. To calculate the impact of the 5P-7P lane closure, we calculate the total user cost = $25,936 when the lane is open 5P-7P (the right column of Method 4). Therefore, keeping the lane closed from 5P to 7P beyond the Announced lane-closed periods costs 37,053 – 25,936 = $11,117.

The Traffic Sheet will not compute user cost for a case with three cost scenarios, as described in Sec. 2.4.3.2, because the threshold capacity and range capacity only accommodate two cost scenarios. For example, we can calculate the user cost for June 16, 1998 using manual methods only, because it contains all three cost scenarios.

2.4.3.3.2 User and Period Costs for Announced, Lane Closed = AC

2.4.3.3.2.1 User Cost

We can calculate user cost for announced lane closures in the same way we did for unannounced lane closures in Sec. 2.4.2.2, Pg. 2-29. In the Summary View for Average Demand, Fig. 2-12, Pg. 2-31, the right column of Method 2 shows average 7A-5P user cost = $25,936 for "24 hr, Announced" lane closure, with no backups. Fig. 2-36 is the Traffic Sheet User Cost View for "24 hr, Announced." Fig. 2-37 is the Daily Sheet User Cost View, for Announced, Lane Closed = AC, which shows the hourly user costs when a lane closure has been properly announced. These hourly user cost values were Paste Valued from the user cost column of Fig. 2-36. Fig. 2-38 is the Detailed Cost View that shows user cost for Announced, Lane Closed = AC, calculated by the Daily Sheet from the input in the User Cost View.

User Cost View

period length (min)	60	
annual traffic growth (%)	0	
years of growth	2	
VEHICLE INPUT	**cars**	**trucks**
design demand (%)	90.0%	10.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.00	$2.00

PROJECT INFORMATION	
PROJECT TITLE	US 00 Overlay
	Example Problem
C.S.	90000
JOB #	00000
START DATE	6/00/98

REPORT INFORMATION	
REPORT TITLE	DETAILED USER COST REPORT
	TRAFFIC SHEET
DIVISION	
REPORT BY	R. I. Carr
REPORT DATE	1/2/97

NOTES:

METHOD INPUT		METHOD 1	
method title		24 hr, Not Announced	
DISTANCE AND SPEED	(mi) (mph)	distance	speed
work zone	method travel	2	see delay
	normal travel	2	65
diversion	method travel	12	50
	normal travel	10	65
SPEED DELAY		threshold	range
capacity for speed delay (V/period)		1400	
speed (when D~0) (mph)		45	
speed (when D=C) (mph)		10	
DECREASE TO DEMAND		threshold	range
capacity for decreases to design demand (V/period)		1400	
canceled cars (with no delay) (%)		5.0%	
canceled trucks (with no delay) (%)			
canceled cars (with delay) (%/min)		1.0%	
canceled trucks (with delay) (%/min)			
diverted cars (with no delay) (%)		5.0%	
diverted trucks (with no delay) (%)			
diverted cars (with delay) (%/min)		1.0%	
diverted trucks (with delay) (%/min)		0.5%	
OTHER USER COST INPUT		cars	trucks
other user cost per vehicle ($/V)		$0.00	$0.00
user cost per diversion ($/V)		$1.53	$2.93

SUMMARY OUTPUT	
traffic method	24 hr, Not Announced
direction	Avg
total user cost	$54,983
user cost of delays	$42,642
user cost of decreases	$12,341
maximum backup (V)	260
maximum backup length (lane mi)	1.5
maximum delay (min.)	21.3
average delay (min)	10.5
total delay, except diversions (V hr)	3,952
total vehicles canceled(V)	4,671
total vehicles diverted (V)	4,850
total decrease in demand (V)	9,521
% decrease in demand	29.7%
delay per diverted vehicle (min)	5.2
total diversion delay (V hr)	418
average delay, including diversions (min)	9.6
total delay, including diversions (V hr)	4,370
user cost / design demand	$1.71
delay cost / actual demand	$1.89

User Cost | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

Direction:	Avg	backup at start (V)		0								
period (hr)	capacity (V/period)	actual demand (V/period)	cancel costs ($)	divert costs ($)	decrease cost cars ($)	decrease cost trucks ($)	delay cost cars ($)	delay cost trucks ($)	decrease cost ($)	delay cost ($)	user cost ($)	user cost / total vehicles ($/V)
12 A	1400	413	$28	$44	$71	$1	$108	$14	$72	$121	$193	$0.41
1 A	1400	261	$16	$25	$41	$0	$48	$6	$42	$54	$95	$0.32
2 A	1400	171	$10	$16	$26	$0	$26	$3	$26	$29	$56	$0.29
3 A	1400	96	$6	$9	$14	$0	$13	$2	$14	$15	$29	$0.27
4 A	1400	102	$6	$9	$15	$0	$14	$2	$15	$16	$32	$0.27
5 A	1400	140	$8	$13	$21	$0	$20	$3	$21	$23	$44	$0.28
6 A	1400	476	$34	$53	$86	$2	$144	$18	$87	$163	$250	$0.46
7 A	1400	1,192	$175	$286	$444	$17	$1,423	$203	$461	$1,627	$2,088	$1.35
8 A	1400	1,528	$366	$603	$926	$43	$3,047	$493	$969	$3,540	$4,509	$1.98
9 A	1400	1,196	$240	$395	$608	$27	$2,022	$311	$635	$2,332	$2,967	$1.76
10 A	1400	1,239	$193	$314	$488	$19	$1,583	$229	$507	$1,811	$2,319	$1.42
11 A	1400	1,341	$236	$386	$597	$25	$1,971	$293	$622	$2,264	$2,885	$1.58
12 P	1400	1,463	$308	$506	$779	$35	$2,587	$403	$814	$2,991	$3,804	$1.82
1 P	1400	1,353	$297	$489	$752	$34	$2,493	$393	$786	$2,886	$3,672	$1.87
2 P	1400	1,431	$302	$496	$764	$34	$2,536	$395	$798	$2,931	$3,729	$1.82
3 P	1400	1,445	$354	$584	$897	$42	$2,942	$480	$939	$3,421	$4,360	$2.01
4 P	1400	1,520	$495	$819	$1,253	$62	$3,876	$698	$1,315	$4,574	$5,889	$2.33
5 P	1400	1,447	$616	$1,023	$1,558	$80	$4,392	$887	$1,638	$5,279	$6,917	$2.56
6 P	1400	1,230	$429	$711	$1,086	$54	$3,292	$609	$1,140	$3,901	$5,042	$2.39
7 P	1400	1,138	$188	$306	$475	$19	$1,557	$228	$494	$1,785	$2,279	$1.50
8 P	1400	1,037	$128	$206	$323	$11	$973	$134	$334	$1,108	$1,442	$1.11
9 P	1400	1,002	$118	$191	$300	$10	$887	$122	$310	$1,008	$1,318	$1.06
10 P	1400	784	$73	$117	$186	$5	$467	$62	$191	$529	$719	$0.77
11 P	1400	563	$43	$68	$108	$2	$208	$27	$110	$235	$346	$0.53
TOT	33600	22,568	$4,671	$7,670	$11,816	$525	$36,628	$6,015	$12,341	$42,642	$54,983	$1.71
MAX	1400	1,528	$616	$1,023	$1,558	$80	$4,392	$887	$1,638	$5,279	$6,917	$2.56
MIN	1400	96	$6	$9	$14	$0	$13	$2	$14	$15	$29	$0.27

Fig. 2-36 User Cost View for "24 hr, Announced"

User Cost View Paste Values

Project:	US 00 Overlay (Example)
By:	R. I. Carr, 7/3/97
Other:	
Method:	Publicity
Traffic:	Lane Closed, Announced

Print	User Cost per Period	
Period (min):	60	15
12 A - 1 A	$187	$47
1 A - 2 A	$83	$21
2 A - 3 A	$45	$11
3 A - 4 A	$23	$6
4 A - 5 A	$25	$6
5 A - 6 A	$35	$9
6 A - 7 A	$247	$62
7 A - 8 A	$1,766	$442
8 A - 9 A	$3,176	$794
9 A - 10 A	$2,029	$507
10 A - 11 A	$1,923	$481
11 A - 12 P	$2,291	$573
12 P - 1 P	$2,819	$705
1 P - 2 P	$2,562	$641
2 P - 3 P	$2,733	$683
3 P - 4 P	$2,970	$742
4 P - 5 P	$3,668	$917
5 P - 6 P	$3,993	$998
6 P - 7 P	$2,850	$713
7 P - 8 P	$1,711	$428
8 P - 9 P	$1,307	$327
9 P - 10 P	$1,212	$303
10 P - 11 P	$710	$178
11 P - 12 A	$348	$87
24 hr	$38,711	

Fig. 2-37 Daily Sheet User Cost View for Announced, Lane Closed = AC

User Cost	Period Cost	Daily Cost	Project Cost

Detailed Cost View | Print | Print w/ Examples

Project:	US 00 Overlay (Example)	Method:	Publicity
By:	R. I. Carr, 7/3/97	Traffic:	ne Closed, Announc
Other:		P/U:	100%

	Cost per Period				
Period (min):	60		15	30	45
Time of Day	Period	Sum			
12 A - 1 A	$187	$187	$47	$93	$140
1 A - 2 A	$83	$270	$21	$42	$62
2 A - 3 A	$45	$315	$11	$23	$34
3 A - 4 A	$23	$338	$6	$11	$17
4 A - 5 A	$25	$363	$6	$12	$18
5 A - 6 A	$35	$398	$9	$18	$26
6 A - 7 A	$247	$645	$62	$124	$185
7 A - 8 A	$1,766	$2,411	$442	$883	$1,325
8 A - 9 A	$3,176	$5,587	$794	$1,588	$2,382
9 A - 10 A	$2,029	$7,616	$507	$1,014	$1,522
10 A - 11 A	$1,923	$9,538	$481	$961	$1,442
11 A - 12 P	$2,291	$11,830	$573	$1,146	$1,718
12 P - 1 P	$2,819	$14,649	$705	$1,409	$2,114
1 P - 2 P	$2,562	$17,211	$641	$1,281	$1,922
2 P - 3 P	$2,733	$19,943	$683	$1,366	$2,050
3 P - 4 P	$2,970	$22,913	$742	$1,485	$2,227
4 P - 5 P	$3,668	$26,580	$917	$1,834	$2,751
5 P - 6 P	$3,993	$30,573	$998	$1,996	$2,994
6 P - 7 P	$2,850	$33,423	$713	$1,425	$2,138
7 P - 8 P	$1,711	$35,134	$428	$855	$1,283
8 P - 9 P	$1,307	$36,441	$327	$653	$980
9 P - 10 P	$1,212	$37,653	$303	$606	$909
10 P - 11 P	$710	$38,363	$178	$355	$533
11 P - 12 A	$348	$38,711	$87	$174	$261
24 hr	$38,711				

Examples

1:00P to 2:00P =	2,562	1:15P to 2:00P =	1,922
1:00P to 3:00P:		7:00A to 5:00P:	
1:00P to 2:00P =	2,562	12:00A to 5:00P =	26,580
2:00P to 3:00P =	2,733	-12:00A to 7:00A =	-645
	5,295		25,936
1:15P to 2:15P:		6:45A to 5:30P:	
1:15P to 2:00P =	1,922	7:00A to 5:00P =	25,936
2:00P to 2:15P =	683	6:45A to 7:00A =	62
	2,605	5:00P to 5:30P =	1,996
			27,993

Fig. 2-38 Detailed Cost View for Announced, Lane Closed = AC

2.4.3.3.2.2 Period Costs

Period costs are calculated as described in Sec. 2.4.2.3. Fig. 2-39 shows the Daily Sheet Period Cost View, which calculates the Announced, Lane Closed = AC period costs from the hourly user costs of Fig. 2-37. We have entered P/U = 33.3%, cost threshold = round-off = $100, as we did for "Lane Closed, Not Announced" in Fig. 2-24 in Sec. 2.4.2.3.3. Fig. 2-40 is the Detailed Cost View that parallels the Period Cost View of Fig. 2-39. Fig. 2-41 shows a Lane-Closure Period Costs table, in which we have reformatted values of Fig. 2-39 in a format that is suitable for contract Special Provisions, without listing hours whose period cost = 0.

Adjustments to User Cost

Fraction = P/U =		**33.3%**
Cost Threshold =		**$100.0**
Roundoff =	**$100**	

Period Cost View

Project:	US 00 Overlay (Example)	
By:	R. I. Carr, 7/3/97	
Other:		
Method:	Publicity	
Traffic:	Lane Closed, Announced	
Print	Cost per Period	
Period (min):	60	15
12 A - 1 A	$0	$0
1 A - 2 A	$0	$0
2 A - 3 A	$0	$0
3 A - 4 A	$0	$0
4 A - 5 A	$0	$0
5 A - 6 A	$0	$0
6 A - 7 A	$0	$0
7 A - 8 A	$600	$150
8 A - 9 A	$1,100	$275
9 A - 10 A	$700	$175
10 A - 11 A	$600	$150
11 A - 12 P	$800	$200
12 P - 1 P	$900	$225
1 P - 2 P	$900	$225
2 P - 3 P	$900	$225
3 P - 4 P	$1,000	$250
4 P - 5 P	$1,200	$300
5 P - 6 P	$1,300	$325
6 P - 7 P	$900	$225
7 P - 8 P	$600	$150
8 P - 9 P	$400	$100
9 P - 10 P	$400	$100
10 P - 11 P	$200	$50
11 P - 12 A	$100	$25
24 hr	$12,600	

Fig. 2-39 Period Cost View for Announced, Lane Closed = AC

User Cost	Period Cost	Daily Cost	Project Cost

Detailed Cost View | Print | Print w/ Examples

Project:	US 00 Overlay (Example)	Method:	Publicity
By:	R. I. Carr, 7/3/97	Traffic:	ıne Closed, Announc
Other:		P/U:	33%

	Cost per Period				
Period (min):	60		15	30	45
Time of Day	Period	Sum			
12 A - 1 A	$0	$0	$0	$0	$0
1 A - 2 A	$0	$0	$0	$0	$0
2 A - 3 A	$0	$0	$0	$0	$0
3 A - 4 A	$0	$0	$0	$0	$0
4 A - 5 A	$0	$0	$0	$0	$0
5 A - 6 A	$0	$0	$0	$0	$0
6 A - 7 A	$0	$0	$0	$0	$0
7 A - 8 A	$600	$600	$150	$300	$450
8 A - 9 A	$1,100	$1,700	$275	$550	$825
9 A - 10 A	$700	$2,400	$175	$350	$525
10 A - 11 A	$600	$3,000	$150	$300	$450
11 A - 12 P	$800	$3,800	$200	$400	$600
12 P - 1 P	$900	$4,700	$225	$450	$675
1 P - 2 P	$900	$5,600	$225	$450	$675
2 P - 3 P	$900	$6,500	$225	$450	$675
3 P - 4 P	$1,000	$7,500	$250	$500	$750
4 P - 5 P	$1,200	$8,700	$300	$600	$900
5 P - 6 P	$1,300	$10,000	$325	$650	$975
6 P - 7 P	$900	$10,900	$225	$450	$675
7 P - 8 P	$600	$11,500	$150	$300	$450
8 P - 9 P	$400	$11,900	$100	$200	$300
9 P - 10 P	$400	$12,300	$100	$200	$300
10 P - 11 P	$200	$12,500	$50	$100	$150
11 P - 12 A	$100	$12,600	$25	$50	$75
24 hr	$12,600				

Examples

1:00P to 2:00P =	900	1:15P to 2:00P =	675
1:00P to 3:00P:		7:00A to 5:00P:	
1:00P to 2:00P =	900	12:00A to 5:00P =	8,700
2:00P to 3:00P =	900	-12:00A to 7:00A =	0
	1,800		8,700
1:15P to 2:15P:		6:45A to 5:30P:	
1:15P to 2:00P =	675	7:00A to 5:00P =	8,700
2:00P to 2:15P =	225	6:45A to 7:00A =	0
	900	5:00P to 5:30P =	650
			9,350

Fig. 2-40 Detailed Cost View for Announced, Lane Closed = AC

Lane Closure Period Costs		
Lane Closure:	Announced, Lane Closed = AC	
	Cost per Period	
Period (min):	60	15
7 A - 8 A	$600	$150
8 A - 9 A	$1,100	$275
9 A - 10 A	$700	$175
10 A - 11 A	$600	$150
11 A - 12 P	$800	$200
12 P - 1 P	$900	$225
1 P - 2 P	$900	$225
2 P - 3 P	$900	$225
3 P - 4 P	$1,000	$250
4 P - 5 P	$1,200	$300
5 P - 6 P	$1,300	$325
6 P - 7 P	$900	$225
7 P - 8 P	$600	$150
8 P - 9 P	$400	$100
9 P - 10 P	$400	$100
10 P - 11 P	$200	$50
11 P - 12 A	$100	$25
Total	$12,600	

Fig. 2-41 Period Costs for Announced, Lane Closed = AC

2.4.3.3.3 User and Period Costs for Announced, Lane Not Closed = AN

As noted in Sec. 2.4.3.2, pg. 2-58, periods for which closure was announced but did not occur can have user costs. When a lane is not closed, there is no backup delay or speed delay. However, there is **decrease delay** if vehicles cancel or divert their trips, because they have been incorrectly informed that a lane will be closed and delays will occur. Therefore, the **decrease cost** for each period in Fig. 2-36 estimates the **user cost** for announcing a lane will be closed when it is not actually closed. From Fig. 2-36 we have Paste Valued into Fig. 2-42 the user cost values for a lane-closure that is Announced, Lane Not Closed = AN. We enter the input values into the Period Cost View (not shown) that we entered in Fig. 2-37 and calculated the period costs shown in Fig. 2-42 for Announced, Lane Not Closed = AN, in parallel with Fig. 2-41 for Announced, Lane Closed = AC.

User Cost View Paste Values

Project:	US 00 Overlay (Example)	
By:	R. I. Carr, 7/1/97	
Other:		
Method:	Publicity	
Traffic:	Announced, Not Closed	
Print	User Cost per Period	
Period (min):	60	15
12 A - 1 A	$58	$14
1 A - 2 A	$25	$6
2 A - 3 A	$14	$3
3 A - 4 A	$7	$2
4 A - 5 A	$7	$2
5 A - 6 A	$11	$3
6 A - 7 A	$77	$19
7 A - 8 A	$667	$167
8 A - 9 A	$1,363	$341
9 A - 10 A	$786	$197
10 A - 11 A	$738	$184
11 A - 12 P	$910	$228
12 P - 1 P	$1,174	$293
1 P - 2 P	$1,043	$261
2 P - 3 P	$1,129	$282
3 P - 4 P	$1,253	$313
4 P - 5 P	$1,635	$409
5 P - 6 P	$1,822	$455
6 P - 7 P	$1,190	$298
7 P - 8 P	$643	$161
8 P - 9 P	$471	$118
9 P - 10 P	$433	$108
10 P - 11 P	$239	$60
11 P - 12 A	$111	$28
24 hr	$15,806	

Fig. 2-42 User Cost for Announced, Lane Not Closed = AN.

Lane Closure Period Costs

Lane Closure:	Announced, Lane Not Closed = AN	
	Cost per Period	
Period (min):	60	15
7 A - 8 A	$200	$50
8 A - 9 A	$500	$125
9 A - 10 A	$300	$75
10 A - 11 A	$200	$50
11 A - 12 P	$300	$75
12 P - 1 P	$400	$100
1 P - 2 P	$300	$75
2 P - 3 P	$400	$100
3 P - 4 P	$400	$100
4 P - 5 P	$500	$125
5 P - 6 P	$600	$150
6 P - 7 P	$400	$100
7 P - 8 P	$200	$50
8 P - 9 P	$200	$50
9 P - 10 P	$100	$25
Total	$5,000	

Fig. 2-43 Period Costs for Announced, Lane Not Closed = AN.

2.4.3.3.4 User and Period Costs for Not Announced, Lane Closed = NC

User costs and period costs for Not Announced, Lane Closed = NC were calculated and described detail in Sec. 2.4.2. Fig. 2-44 shows these period costs, in the same format as Fig. 2-42 and Fig. 2-41. Together, these three tables show the period costs for all possible scenarios for each period of time.

Lane Closure Period Costs

Lane Closure:	Not Announced, Lane Closed = NC	
	Cost per Period	
Period (min):	60	15
7 A - 8 A	$700	$175
8 A - 9 A	$1,500	$375
9 A - 10 A	$1,000	$250
10 A - 11 A	$800	$200
11 A - 12 P	$1,000	$250
12 P - 1 P	$1,300	$325
1 P - 2 P	$1,200	$300
2 P - 3 P	$1,200	$300
3 P - 4 P	$1,500	$375
4 P - 5 P	$2,000	$500
5 P - 6 P	$2,300	$575
6 P - 7 P	$1,700	$425
7 P - 8 P	$800	$200
8 P - 9 P	$500	$125
9 P - 10 P	$400	$100
10 P - 11 P	$200	$50
11 P - 12 A	$100	$25
Total	$18,200	

Fig. 2-44 Period Costs for Not Announced, Lane Closed = NC

2.4.3.4 Manual Calculations

2.4.3.4.1 Equations

Estimates of user costs or period costs from a combination of methods can be calculated manually, by summing the applicable user costs or period cost of the periods. Calculations use a variation of Eq. (24), in which method *a* is used for periods *i* to *j* and method *b* for periods *j*+1 to *m*.

$$(cost)_{i \text{ to } m} = (cost)_{(i \text{ to } j),a} + (cost)_{(j+1 \text{ to } m),b} \quad (34)$$

More generally, to calculate $(cost)_{j \text{ to } m}$ = *user cost* or *period cost* for periods from *j* to *m*, where $(cost)_{ik}$ = *cost* for period *i* using method *k*, where *k* = actual method used,

$$(cost)_{j \text{ to } m} = \sum_{i=j \text{ to } m} (cost)_{ik} \quad (35)$$

2.4.3.4.2 User Cost

We can use these equations to calculate user cost for 7A-5P Announced + 5P-7P Not Announced, in which method AC is used for 7A-5P Announced, and method NC is used for 5P-7P Not Announced. We calculate 7A-7P user cost = (7A-5P user cost = $25,936 from Fig. 2-38) + (5P-7P user cost = 6,917 + 5,042 = $11,959 from Fig. 2-17) = $37,895. This is $842 = 2% above "7A-5P A; 5P-7P NA" user cost = $37,053 computed by the Traffic Sheet and shown in the Summary View of Fig. 2-12.

We noted in Sec. 2.4.3.3.1 that the CO^3 Traffic Sheet cannot calculate user costs for 24 hours that have more than two scenarios, such as June 16, 1998. However, we can manually using Eq. (35), as shown below:

1.	Announced, Lane-Closed = AC (from Fig. 2-38)				
	7A-8A	60 min		$1,766	
	8A-9A	15 min		794	
	11A-12P	30 min		1,146	
	12P-1P	60 min		2,819	
	1P-2P	60 min		2,562	
	2P-3P	60 min		2,733	
	3P-4P	60 min		2,970	
	4P-5P	60 min		3,668	$18,458
2.	Announced, Lane Not Closed = AN (from Fig. 2-42)				
	8A-9A	45 min	(3 * 341 =)	1,023	
	11A-12P	30 min	(2 * 228 =)	456	1,479
3.	Not Announced, Lane Closed = NC (from Fig. 2-19)				
	5P-6P	15 min		1,729	1,729
	Total User Cost				$21,666

2.4.3.4.3 Period Cost

We can calculate period costs manually the same way we calculate user cost. We substitute period cost for user cost in the calculations above, to calculate 7A-7P period cost = (7A-5P Announced period cost = $8,700 from Fig. 2-40) + (5P-7P Not Announced period cost = 2,300 + 1,700 = $4,000 from Fig. 2-44) = $12,700.

Similarly, we calculate period cost for June 16, 1988 in the following table:

1.	Announced, Lane Closed = AC (from Fig. 2-40)				
	7A-8A	60 min		$600	
	8A-9A	15 min		275	
	11A-12P	30 min		400	
	12P-1P	60 min		900	
	1P-2P	60 min		900	
	2P-3P	60 min		900	
	3P-4P	60 min		1,000	
	4P-5P	60 min		1,200	$6,175
2.	Announced, Lane Not Closed = AN (from Fig. 2-43)				
	8A-9A	45 min	(3 * 125 =)	375	
	11A-12P	30 min	(2 * 75 =)	150	525
3.	Not Announced, Lane Closed = NC (from Fig. 2-44)				
	5P-6P	15 min		575	575
	Total Period Cost				$7,275

2.4.3.5 Actual User Cost and Period Cost

2.4.3.5.1 Actual Lane Closures

As in earlier sections, we assume that HiWay Construction Company won the contract. Fig. 2-45 shows actual project lane closures by HiWay, a total of 13 days, with the first lane-closure on June 10, 1998, and the last on July 2, 1998, 22 days later. Based on its work plan and on weather reports, HiWay announced lane-closures for 7A-5P on June 10-12, June 15-17, June 22-25, and June 30-July 1, totaling 12 days of 10 hr = 120 hr. These are shown as a shaded area in Fig. 2-45**.** HiWay closed a lane 7A-5P some days, but lane closure varied from day to day to fit the work needs, as HiWay selected lane closure periods with one eye on the contract period cost. HiWay was stopped by weather only once, on June 22 until 10:00A. HiWay found on reaching July 1 that it still needed a portion of a day to finish. With good weather in sight, HiWay chose to finish July 2, though this lane closure was not announced, rather than wait until after July 4 week-end to announce and finish the work at reduced period cost.

		Period (1 hr)	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	Lane Closed Hours (hr)
Day	Date	Lane Closure Times	Fraction of Hour Lane is Closed (hr)											
1	6/10/98	7A-5P	1	1	1	1	1	1	1	1	1	1		10.00
2	6/11/98	7A-5P	1	1	1	1	1	1	1	1	1	1		10.00
3	6/12/98	7A-4P	1	1	1	1	1	1	1	1	1			9.00
4	6/15/98	7:30A-5:45P	0.5	1	1	1	1	1	1	1	1	1	0.75	10.25
5	6/16/98	7A-8:15A, 11:30A-5:15P	1	0.25			0.5	1	1	1	1	1	0.25	7.00
6	6/17/98	7A-4:30P		1	1	1	1	1	1	1	1	0.5		8.50
7	6/22/98	10A-4:45				1	1	1	1	1	1	0.75		6.75
8	6/23/98	7A-5P	1	1	1	1	1	1	1	1	1	1		10.00
9	6/24/98	7A-4:45P	1	1	1	1	1	1	1	1	1	0.75		9.75
10	6/25/98	7:15A-4:30P	0.75	1	1	1	1	1	1	1	1	0.5		9.25
11	6/30/98	9A-3:30P			1	1	1	1	1	1	0.5			6.50
12	7/1/98	7A-3P	1	1	1	1	1	1	1	1				8.00
13	7/2/98	9A-2:30P			1	1	1	1	1	0.5				5.50
		Total Periods (hr)	8.25	9.25	11	12	12.5	13	13	12.5	10.5	7.5	1	110.50

Fig. 2-45 Actual Lane-Closed Hours and Announced Lane-Closed Hours

2.4.3.5.2 Actual Project User Cost

Actual project user cost is the sum of AC, AN, and NC user cost. Fig. 2-46 shows actual project AC user cost. Of the 120 hr announced, a lane was actually closed **AC =** 104 hr, and **AC user cost** = $267,786. Fig. 2-47 shows **AN user cost** = $18,252 for **AN =** 120 – 104 = 16 hr of lane closure that was announced but not implemented. Fig. 2-48 shows **NC** = 6.5 hr, primarily on July 2, for which **NC user cost** = $24,429. **Total project user cost** = 267,786 + 18,252 + 24,429 = $310,449.

Project Cost View User | Period | Detailed | Daily

Project:	US 00 Overlay (Example)	Period (1 hr)	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P
By:	R. I. Carr, 7/3/97												
Other:													
Method:	Publicity	Cost per Period ($/hr)	$1,766	$3,176	$2,029	$1,923	$2,291	$2,819	$2,562	$2,733	$2,970	$3,668	$3,993
Traffic:	Lane Closed, Announced												
P/U:	100.0% Paste Values												

Print — Daily

Day	Date	Lane Closure Times	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	Lane Closed Hours (hr)	Period Cost ($)
			Fraction of Hour Lane is Closed (hr)												
1	6/10/98	7A-5P	1	1	1	1	1	1	1	1	1	1		10.00	$25,936
2	6/11/98	7A-5P	1	1	1	1	1	1	1	1	1	1		10.00	$25,936
3	6/12/98	7A-4P	1	1	1	1	1	1	1	1	1			9.00	$22,268
4	6/15/98	7:30A-5:45P	0.5	1	1	1	1	1	1	1	1	1		9.50	$25,053
5	6/16/98	7A-8:15A, 11:30A-5:15P	1	0.25			0.5	1	1	1	1	1		6.75	$18,457
6	6/17/98	7A-4:30P		1	1	1	1	1	1	1	1	0.5		8.50	$22,336
7	6/22/98	10A-4:45				1	1	1	1	1	1	0.75		6.75	$18,048
8	6/23/98	7A-5P	1	1	1	1	1	1	1	1	1	1		10.00	$25,936
9	6/24/98	7A-4:45P	1	1	1	1	1	1	1	1	1	0.75		9.75	$25,019
10	6/25/98	7:15A-4:30P	0.75	1	1	1	1	1	1	1	1	0.5		9.25	$23,660
11	6/30/98	9A-3:30P			1	1	1	1	1	1	0.5			6.50	$15,841
12	7/1/98	7A-3P	1	1	1	1	1	1	1	1				8.00	$19,298
13	7/2/98	9A-2:30P												0.00	$0
Totals		Total Periods (hr)	8.25	9.25	10	11	11.5	12	12	12	10.5	7.5		104.00	$267,786
	Print	Total Cost ($)	$14,570	$29,378	$20,288	$21,149	$26,349	$33,828	$30,745	$32,793	$31,181	$27,507		**$267,786**	

Fig. 2-46 Project Cost View of User Cost for Project Duration for Announced, Lane Closed = AC

Project Cost View User | Period | Detailed | Daily

Project:	US 00 Overlay (Example)	Period (1 hr)	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	6 P - 7 P
By:	R. I. Carr, 7/1/97													
Other:														
Method:	Publicity	Cost per Period ($/hr)	$667	$1,363	$786	$738	$910	$1,174	$1,043	$1,129	$1,253	$1,635	$1,822	$1,190
Traffic:	Announced, Not Closed													
P/U:	100.0% Paste Values													

Print — Daily

Day	Date	Lane Closure Times	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	6 P - 7 P	Lane Closed Hours (hr)	Period Cost ($)
			Fraction of Hour Lane is Closed (hr)													
1	6/10/98	7A-5P													0.00	$0
2	6/11/98	7A-5P													0.00	$0
3	6/12/98	7A-4P										1			1.00	$1,635
4	6/15/98	7:30A-5:45P	0.5												0.50	$334
5	6/16/98	7A-8:15A, 11:30A-5:15P		0.75	1	1	0.5								3.25	$3,001
6	6/17/98	7A-4:30P	1									0.5			1.50	$1,485
7	6/22/98	10A-4:45	1	1	1							0.25			3.25	$3,225
8	6/23/98	7A-5P													0.00	$0
9	6/24/98	7A-4:45P										0.25			0.25	$409
10	6/25/98	7:15A-4:30P	0.25									0.5			0.75	$984
11	6/30/98	9A-3:30P	1	1							0.5	1			3.50	$4,291
12	7/1/98	7A-3P									1	1			2.00	$2,888
13	7/2/98	9A-2:30P													0.00	$0
14																
15																
Totals		Total Periods (hr)	3.75	2.75	2	1	0.5				1.5	4.5			16.00	$18,252
	Print	Total Cost ($)	$2,502	$3,748	$1,573	$738	$455				$1,879	$7,358			**$18,252**	

Fig. 2-47 Project Cost View of User Cost for Project Duration for Announced, Lane Not Closed = AN

Project Cost View | User | Period | Detailed | Daily

Project:	US 00 Overlay (Example)		Period (1 hr)	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	Print Daily
By:	R. I. Carr, 7/1/97														
Other:															
Method:	No Publicity		Cost per Period ($/hr)	$2,088	$4,509	$2,967	$2,319	$2,885	$3,804	$3,672	$3,729	$4,360	$5,889	$6,917	
Traffic:	Lane Closed														
P/U:	100.0%	Paste Values													
Day	Date	Lane Closure Times		Fraction of Hour Lane is Closed (hr)											Lane Closed Hours (hr)	Period Cost ($)
1	6/10/98	7A-5P													0.00	$0
2	6/11/98	7A-5P													0.00	$0
3	6/12/98	7A-4P													0.00	$0
4	6/15/98	7:30A-5:45P												0.75	0.75	$5,188
5	6/16/98	7A-8:15A, 11:30A-5:15P												0.25	0.25	$1,729
6	6/17/98	7A-4:30P													0.00	$0
7	6/22/98	10A-4:45													0.00	$0
8	6/23/98	7A-5P													0.00	$0
9	6/24/98	7A-4:45P													0.00	$0
10	6/25/98	7:15A-4:30P													0.00	$0
11	6/30/98	9A-3:30P													0.00	$0
12	7/1/98	7A-3P													0.00	$0
13	7/2/98	9A-2:30P				1	1	1	1	1	0.5				5.50	$17,512
Totals		Total Periods (hr)				1	1	1	1	1	0.5			1	6.50	$24,429
		Print	Total Cost ($)			$2,967	$2,319	$2,885	$3,804	$3,672	$1,864			$6,917	**$24,429**	

Fig. 2-48 Project Cost View of User Cost for Project Duration for Not Announced, Lane Closed = NC

Project Cost View | User | Period | Detailed | Daily

Project:	US 00 Overlay (Example)		Period (1 hr)	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	Print Daily
By:	R. I. Carr, 7/3/97														
Other:															
Method:	Publicity		Cost per Period ($/hr)	$600	$1,100	$700	$600	$800	$900	$900	$900	$1,000	$1,200	$1,300	
Traffic:	Lane Closed, Announced														
P/U:	33.3%	Paste Values													
Day	Date	Lane Closure Times		Fraction of Hour Lane is Closed (hr)											Lane Closed Hours (hr)	Period Cost ($)
1	6/10/98	7A-5P		1	1	1	1	1	1	1	1	1	1		10.00	$8,700
2	6/11/98	7A-5P		1	1	1	1	1	1	1	1	1	1		10.00	$8,700
3	6/12/98	7A-4P		1	1	1	1	1	1	1	1	1			9.00	$7,500
4	6/15/98	7:30A-5:45P		0.5	1	1	1	1	1	1	1	1	1		9.50	$8,400
5	6/16/98	7A-8:15A, 11:30A-5:15P		1	0.25			0.5	1	1	1	1	1		6.75	$6,175
6	6/17/98	7A-4:30P			1	1	1	1	1	1	1	1	0.5		8.50	$7,500
7	6/22/98	10A-4:45					1	1	1	1	1	1	0.75		6.75	$6,000
8	6/23/98	7A-5P		1	1	1	1	1	1	1	1	1	1		10.00	$8,700
9	6/24/98	7A-4:45P		1	1	1	1	1	1	1	1	1	0.75		9.75	$8,400
10	6/25/98	7:15A-4:30P		0.75	1	1	1	1	1	1	1	1	0.5		9.25	$7,950
11	6/30/98	9A-3:30P				1	1	1	1	1	1	0.5			6.50	$5,300
12	7/1/98	7A-3P		1	1	1	1	1	1	1	1				8.00	$6,500
13	7/2/98	9A-2:30P													0.00	$0
Totals		Total Periods (hr)		8.25	9.25	10	11	11.5	12	12	12	10.5	7.5		104.00	$89,825
		Print	Total Cost ($)	$4,950	$10,175	$7,000	$6,600	$9,200	$10,800	$10,800	$10,800	$10,500	$9,000		**$89,825**	

Fig. 2-49 Project Cost View of Period Cost for Project Duration for Announced, Lane Closed = AC

Project Cost View User | Period | Detailed | Daily

Project:	US 00 Overlay (Example)
By:	R. I. Carr, 7/1/97
Other:	
Method:	Publicity
Traffic:	Announced, Not Closed
P/U:	33.3% Paste Values

Day	Date	Lane Closure Times	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	6 P - 7 P	Lane Closed Hours (hr)	Period Cost ($)
		Period (1 hr) / Cost per Period ($/hr)	$200	$500	$300	$200	$300	$400	$300	$400	$400	$500	$600	$400	Print Daily	
			Fraction of Hour Lane is Closed (hr)													
1	6/10/98	7A-5P													0.00	$0
2	6/11/98	7A-5P													0.00	$0
3	6/12/98	7A-4P										1			1.00	$500
4	6/15/98	7:30A-5:45P	0.5												0.50	$100
5	6/16/98	7A-8:15A, 11:30A-5:15P		0.75	1	1	0.5								3.25	$1,025
6	6/17/98	7A-4:30P	1									0.5			1.50	$450
7	6/22/98	10A-4:45	1	1	1							0.25			3.25	$1,125
8	6/23/98	7A-5P													0.00	$0
9	6/24/98	7A-4:45P										0.25			0.25	$125
10	6/25/98	7:15A-4:30P	0.25									0.5			0.75	$300
11	6/30/98	9A-3:30P	1	1							0.5	1			3.50	$1,400
12	7/1/98	7A-3P									1	1			2.00	$900
13	7/2/98	9A-2:30P													0.00	$0
14																
15																
Totals		Total Periods (hr)	3.75	2.75	2	1	0.5				1.5	4.5			16.00	$5,925
	Print	Total Cost ($)	$750	$1,375	$600	$200	$150				$600	$2,250			$5,925	

Fig. 2-50 Project Cost View of Period Cost for Project Duration for Announced, Lane Not Closed = AN

Project Cost View User | Period | Detailed | Daily

Project:	US 00 Overlay (Example)
By:	R. I. Carr, 7/1/97
Other:	
Method:	No Publicity
Traffic:	Lane Closed
P/U:	33.3% Paste Values

Day	Date	Lane Closure Times	7 A - 8 A	8 A - 9 A	9 A - 10 A	10 A - 11 A	11 A - 12 P	12 P - 1 P	1 P - 2 P	2 P - 3 P	3 P - 4 P	4 P - 5 P	5 P - 6 P	Lane Closed Hours (hr)	Period Cost ($)
		Period (1 hr) / Cost per Period ($/hr)	$700	$1,500	$1,000	$800	$1,000	$1,300	$1,200	$1,200	$1,500	$2,000	$2,300	Print Daily	
			Fraction of Hour Lane is Closed (hr)												
1	6/10/98	7A-5P												0.00	$0
2	6/11/98	7A-5P												0.00	$0
3	6/12/98	7A-4P												0.00	$0
4	6/15/98	7:30A-5:45P											0.75	0.75	$1,725
5	6/16/98	7A-8:15A, 11:30A-5:15P											0.25	0.25	$575
6	6/17/98	7A-4:30P												0.00	$0
7	6/22/98	10A-4:45												0.00	$0
8	6/23/98	7A-5P												0.00	$0
9	6/24/98	7A-4:45P												0.00	$0
10	6/25/98	7:15A-4:30P												0.00	$0
11	6/30/98	9A-3:30P												0.00	$0
12	7/1/98	7A-3P												0.00	$0
13	7/2/98	9A-2:30P			1	1	1	1	1	0.5				5.50	$5,900
Totals		Total Periods (hr)			1	1	1	1	1	0.5			1	6.50	$8,200
	Print	Total Cost ($)			$1,000	$800	$1,000	$1,300	$1,200	$600			$2,300	$8,200	

Fig. 2-51 Project Cost View of Period Cost for Project Duration for Not Announced, Lane Closed = NC

2.4.3.5.3 Actual Project Period Cost

Actual project *period cost* is the sum of AC, AN, and NC period cost. Fig. 2-49 shows actual project AC periods. Of the 120 hr announced, a lane was actually closed **AC** = 104 hr, and **AC period cost** = $89,825. Fig. 2-50 shows **AN period cost** = $5,925 for **AN** = 120 – 104 = 16 hr of lane closure that was announced but not implemented. Fig. 2-51 shows **NC** = 6.5 hr, primarily on July 2, for which **NC period cost** = $8,200. **Total project period cost** = 89,825 + 5,925 + 8,200 = $103,950.

Given P/U ratio and actual project period cost, we can back-calculate actual user cost ≈ (project period cost) / (P/U). For P/U = 33.3% in this example, actual **user cost** ≈ (103,950) / (33.3%) = $312,162. This is close to $310,449 calculated directly in Sec. 2.4.3.5.2, without round-off.

2.4.3.6 Contract Special Provisions

2.4.3.6.1 Introduction

In Sec. 2.4.2.3.7 we dealt with various forms of contract Special Provisions for performing the work in the standard method with no publicity program, in which the contractor closes a lane as needed. We will now consider various forms of contract Special Provisions when the work is performed during lane closures that are properly announced in a public information program. We will assume that we have completed competitive bidding, and HiWay Construction Company (a fictitious company) was low bidder. We assume HiWay's bid price under the Standard Case with no special provisions related to period cost would be $500,000, by coincidence the same project cost estimated in Sec. 2.2.5.2.2. In the following sections, we will consider the impact of Special Provisions based on the lane closure period costs in Fig. 2-41, Fig. 2-43, and Fig. 2-44, on HiWay's bid and on the actual contract amount. The three common contract types which we consider provide needed flexibility are "incentive / disincentive" (I/D) contracts, "rent-a-lane" (RL) contracts, and "A and B" (A+B) contracts. In the example below, we see that they are quantitatively equivalent.

2.4.3.6.2 Incentive / Disincentive (I/D) Contracts

This example of I/D contract provisions parallels Sec. 2.4.2.4.3.2 for I/D contract provisions for daytime work without publicity. The **traffic control method** we use as a baseline for daytime work, with publicity, is "7A-5P, Publicity". Estimated **lane-closed days** = 12 days provides a good contract duration base line for contract incentives and disincentives. From Fig. 2-41 (or Fig. 2-39 or Fig. 2-40), we calculate that 7A-5P AC **period cost** = $8,700.

For contractors that plan their work well, the primary reasons for a lane not being closed when announced are either weather or not needing a full day to do what had been planned to take a full day. We consider the first of these in setting the contract period cost for the Department. We estimate that performing 12 days of work will require announcing 14 days of lane closure, of which 2 days will not be implemented due to bad weather. From Fig. 2-43, we calculate that 7A-5P AN period cost = $3,500. Therefore, we calculate **estimated project period cost** = 12 * 8,700 + 2 * 3,500 = 104,400 + 7,000 = $111,400. We therefore set **contract period cost** = estimated project period cost = $111,400. Actual project lane closure data will be recorded during construction and multiplied by the appropriate period cost values shown in the lane closure period cost tables of Fig. 2-41, Fig. 2-43, and Fig. 2-44 to determine actual period cost. At contract completion, actual contract amount will be decreased or increased by the amount by which actual project period cost is less than or greater than contract period cost = $111,400, in accord with Eq. (27).

We will assume HiWay reviewed the period cost provisions in Fig. 2-41, Fig. 2-43, and Fig. 2-44. HiWay determined that $6,000 additional construction cost would (1) reduce its lane closure time to 11 days of 7A-5P = 10 hr and (2) allow it to announce and schedule work on days for which good weather is predicted. Period cost for Announced, Lane Closed = AC, 7A-5P = $8,700. HiWay predicts there is a 50% probability it will lose 1 day to bad weather. Period cost for Announced, Lane Not Closed = AC, 7A-5P = $3,500. Therefore, its **estimated period cost** = 11 * 8,700 + 0.5 * 3,500 = 95,700 + 1,750 = $97,450, which is 111,400 – 97,450 = $13,950 below contract period cost = $111,400. This will earn a $13,950 incentive. Bidding competitively, HiWay changes its bid to earn the same profit as without the incentive provision. Therefore, it reduces its bid from $500,000 to 500,000 – (13,950 – 6,000) = 500,000 – 7, 950 = $492,050. HiWay expects to earn, at the end of the project, contract cost = 492,050 + 13,950 = $506,000.

We saw in Sec. 2.4.3.5.3, Pg. 2-73, that **actual period cost** = $103,750. Thus, the contract amount would be increased by (contract period cost) – (actual period cost) = 111,400 – 103,750 = $7,650 which produces **contract cost** = 492,050 + 7,650 = $499,700. Therefore, the actual contract cost that results from the I/D provision costs the Department 499,700 – 500,000 = $300 less than without the I/D provision, which is not a significant difference. This is 97,450 – 103,750 = $6,300 less than if HiWay's original estimate of user cost had been correct, and HiWay's under-estimating has cost HiWay $6,300.

From Sec. 2.4.3.5.2, **actual user cost** = $310,449. The Impact Sheet of Fig. 2-8 showed 7A-5P, Publicity user cost = $311,091, which is not substantially different from $311,250. Therefore, the I/D provision itself neither cost the Department more than otherwise, nor did it save user cost. However, the Department would have been happy for HiWay to have completed the project within HiWay's original estimated period cost, which would have brought HiWay the same profit as without the I/D provision. The Department would have paid $6,300 more, but it would have saved the public about 6,300 / 33.3% = $18,900 in user cost. More important, however, is that the I/D provision implemented the 7A-5P, Publicity method, which produced **user cost savings** = 440,114 – 310,449 = $129,665, or about $130,000, at no cost to the Department, except for its $16,000 cost for the publicity program. Had HiWay's estimated period cost been correct, the Department would have paid about $6,000 more and achieved overall user cost savings of about $149,000.

2.4.3.6.3 Rent-A-Lane (RL) Contracts

I/D provisions, and the calculations of Sec. 2.4.3.6.2 for I/D provisions are applicable to RL contract provisions. Continuing with the same example, for RL provisions the Department sets a **target lane rental** = $102,000, a little lower than its estimated **lane closure cost** = $111,400 which was calculated in Sec. 2.4.3.6.2.

Under a RL provision with period cost shown in Fig. 2-41, Fig. 2-43, and Fig. 2-44, the contractor, HiWay bids its Standard Case contract amount plus its additional costs to lower its lane-closure cost plus its estimated lane rental fee. The period cost values for the RL provision are the same as for the I/D provision, so HiWay would see the same incentive to reduce lane-closures with RL it would see with I/D, and HiWay would select the same lane closure plan. HiWay's lane closure plan developed for I/D has an **estimated lane rental fee** = 97,450 – 102,000 = – $4,550. Therefore, with the RL provision HiWay's **bid** = 500,000 + 6,000 – 4,550 = $501,450, at which HiWay expects to earn **contract cost** = 501,450 + 4,550 = $506,000, the same as with an I/D provision.

HiWay's $501,450 bid wins, actual lane closure is as shown in Fig. 2-45, HiWay pays **lane rental** = 103,750 – 102,000 = $1,750, for actual **contract cost** = 501,450 – 1,750 = $499,700, just as with I/D. The Department pays $300 less than for the Standard Case, with no savings in user cost due to LR provisions. However, the RL provisions implemented the 7A-5P, Publicity method, which reduced user cost by about $130,000 relative to 7A-5P without publicity, at no cost to the Department, except for its $16,000 cost for the publicity program. As with I/D, had HiWay's estimated period cost been correct, the Department would have paid about $6,000 more and achieved overall user cost savings of about $149,000.

If the Department sets **target lane rental** = $111,400, all (RL) values would be identical to the I/D example. Conversely, if the lane rental fee is **zero-budget based**, the **target rental fee** = 0, for which HiWay's bid = 500,000 + 6,000 + 97,450 = $603,450, for which HiWay expects to earn estimated **contract cost** = $506,000, as in the other cases.

2.4.3.6.4 A plus B (A+B) Contracts

A+B contract provisions parallel I/D and RL provisions, and the calculations of both Sec. 2.4.3.6.2 for I/D and Sec. 2.4.3.6.3 for RL are applicable to A+B provisions. For A+B provisions, the Department includes Fig. 2-41, Fig. 2-43, and Fig. 2-44 in its bid documents to specify period cost. **Estimated project period cost** = $111,400, as calculated for I/D in Sec.2.4.3.6.2

HiWay bids its Standard Case contract amount plus its additional costs to lower its lane closure cost. The period cost values for the A+B provision are the same as for the I/D and RL provisions, so HiWay would see the same incentive to reduce lane closures with A+B it would see with I/D and RL, and HiWay would select the same lane closure plan. Therefore, with the A+B provision HiWay **bids *A*** = 500,000 + 6,000 = $506,000, expecting to earn estimated **contract cost** = $506,000, the same as with an I/D provision or an RL provision. HiWay's lane closure plan is the same as would be developed for I/D, with **bid *B*** = 97,450 – 102,000 = – $4,550. HiWay's **total bid** = *A* + *B* = 506,000 – 4,550 = $501,450, the same as for an RL provision, which competes with other contractors' bids.

HiWay's $501,450 bid wins, actual lane closure is as shown in Fig. 2-45, **actual period cost** = 103,750 – 102,000 = $1,750, and **contract cost** = 506,000 – (1,750 + 4,550) = $499,700, just as with I/D and RL. The Department pays $300 less than for the Standard Case, with no savings in user cost due to LR provisions, as with I/D and RL.. However, the A+B provisions implemented the 7A-5P, Publicity method, which produced **user cost savings** ≈ $130,000 relative to 7A-5P without publicity, at no cost to the Department, except for its $16,000 cost for the publicity program. As with I/D or LR, had HiWay's estimated period cost been correct, the Department would have paid about $6,000 more and achieved overall **user cost savings** ≈ $149,000.

2.4.3.6.5 Nighttime Construction - Liquidated Damages for Daytime Closure

As we discussed in Sec. 2.4.1.4, pg. 2-28, if the contract requires work to be done at night, there is no need for contract period cost for nighttime lane closures. However, A typical manner of enforcing contract provisions regarding lane closure is to include liquidated damages in the construction contract. In the case of nighttime work, liquidated damages can be an instrument with which to enforce contract provisions that prohibit daytime lane closures. Liquidated damages act as a disincentive to a contractor closing a lane during the day and to reimburse the public (in the form of the Department) for its user cost. Therefore, liquidated damages should not exceed user cost. Fig. 2-52 is an example of **liquidated damages** = user cost, rounded-off to $100 for 8A-8P, calculated by the Period Cost View and based on the User Cost View of Fig. 2-17, pg. 2-37. Conversely, liquidated damages can indicate the Department considers it appropriate to encourage a contractor to close a lane when doing so will save the contractor more than the resulting liquidated damages incurred. Using liquidated damages in this manner parallels the use of period cost in I/D, RL, and A+B Special Provisions, and **liquidated damages** = period cost < user cost is appropriate. Fig. 2-53 is such a table of liquidated damages, which contains the same values for 8A-8P as Fig. 2-24, pg. 2-46, which are 33.3% of user cost, rounded-off to $100.

We generally do not want to set liquidated damages completely out of range of regular contract cost, unless the actions for which damages will incurred are meant to be absolutely prohibited. Fig. 2-8 and Fig. 2-10 shows estimated labor related costs for the Standard Case = $150,000 for 120 paid hours. This represents labor related costs of $1,250/hr. Therefore, the liquidated damages in Fig. 2-52 are too high by this criteria; whereas, Fig. 2-53 is not.

Liquidated Damages

	Cost per Period	
Period (min):	60	15
8 A - 9 A	$4,500	$1,125
9 A - 10 A	$3,000	$750
10 A - 11 A	$2,300	$575
11 A - 12 P	$2,900	$725
12 P - 1 P	$3,800	$950
1 P - 2 P	$3,700	$925
2 P - 3 P	$3,700	$925
3 P - 4 P	$4,400	$1,100
4 P - 5 P	$5,900	$1,475
5 P - 6 P	$6,900	$1,725
6 P - 7 P	$5,000	$1,250
7 P - 8 P	$2,300	$575

Fig. 2-52 Liquidated Damages for Daytime Closure at User Cost

Liquidated Damages

	Cost per Period	
Period (min):	60	15
8 A - 9 A	$1,500	$375
9 A - 10 A	$1,000	$250
10 A - 11 A	$800	$200
11 A - 12 P	$1,000	$250
12 P - 1 P	$1,300	$325
1 P - 2 P	$1,200	$300
2 P - 3 P	$1,200	$300
3 P - 4 P	$1,500	$375
4 P - 5 P	$2,000	$500
5 P - 6 P	$2,300	$575
6 P - 7 P	$1,700	$425
7 P - 8 P	$800	$200

Fig. 2-53 Liquidated Damages for Daytime Closure at One-Third User Cost

CONSTRUCTION
CONGESTON
COST

CO^3 USER MANUAL

CHAPTER 3

CONSTRUCTION TRAVEL ROUTES

3.1 ROUTE CALCULATIONS

3.1.1 INTRODUCTION

Work zones can disturb normal traffic, (1) requiring vehicles to travel more slowly through the work zone or detour or (2) leading vehicles to divert to alternate route(s) that are generally longer and/or slower or (3) leading drivers to cancel trips. Travel on the normal route at normal speed is called **normal travel**, and travel through or around the work zone during construction work (such as during a lane closure) is called **method travel**. There are four modes by which a vehicle can travel between two points:

- **work zone method travel** is travel through the work zone during periods in which construction is performed, or travel on a required detour around the work zone, if present.
- **work zone normal travel** is the alternative to work zone method travel, before or after construction has been performed.
- **diversion method travel** is travel around the work zone (or required detour, if present) that drivers select to avoid going through the work zone (or required detour, if present).
- **diversion normal travel** is the alternative to diversion method travel, before or after construction has been performed.

Sec. 1.5.1.5, pg. 1-10 describes travel distances and speeds more clearly, and Fig. 1-3 Work Zone and Diversion Distances, pg. 1-11 illustrates the four routes, with and without a detour.

Delay caused by the slower speeds of traveling through the work zone we call **speed delay**. Delay due to increased distance and/or decreased speeds of diverting to an alternate route is **diversion delay**. Therefore, in general,

delay = method travel time – normal travel time (36)

speed delay = work zone method travel time
– work zone normal travel time (37)

diversion delay = diversion method travel time (38)
– diversion normal travel time

The basic relationship among L = travel distance, S = travel speed, and T = travel time for route segment i is described by

$$T_i = \frac{L_i}{S_i} \tag{39}$$

3.1.2 COMBINATION OF DISTANCES, TIMES, AND SPEEDS ALONG A ROUTE

We often need to calculate total distance and time and average distance, time, and speed for segments of travel that make up a route. Distances and times can be added to calculate the total distance and time for a route of *N* segments.

$$L_{total} = \sum_{i=1 \text{ to } N} L_i \tag{40}$$

$$T_{total} = \sum_{i=1 \text{ to } N} T_i = \sum_{i=1 \text{ to } N} \frac{L_i}{S_i} \tag{41}$$

Average speed along a route made up of *N* segments is calculated from

$$S_{average} = \frac{L_{total}}{T_{total}} = \frac{\sum_{i=1 \text{ to } N} L_i}{\sum_{i=1 \text{ to } N} \frac{L_i}{S_i}} \tag{42}$$

Note the following inequality:

$$S_{average} \neq \frac{\sum_{i=1 \text{ to } N} S_i}{N} = \frac{\sum_{i=1 \text{ to } N} \frac{L_i}{T_i}}{N} \tag{43}$$

3.1.3 EQUIVALENT DISTANCE, TIME, AND SPEED FOR A GROUP OF ROUTES

Often, different vehicles will select different routes among which to divert. In this instance, we need to determine distance, time, and speed values for a route that is equivalent to a group of *N* routes, based on V_i = the number of vehicles that travel route *i*, and W_i = fraction of vehicles that travel each route *i*, where $i = 1$ to *N*. This can be called the **equivalent route** or **average route**.

We calculate total vehicles, travel distance, and travel time from the following:

$$V_{total} = \sum_{i=1 \text{ to } N} V_i \tag{44}$$

$$L_{total} = \sum_{i=1 \text{ to } N} V_i L_i \tag{45}$$

$$T_{total} = \sum_{i=1 \text{ to } N} V_i \frac{L_i}{S_i} \tag{46}$$

The fraction of vehicles that travel route *i* = **% that take route** *i*, which we also call the W_i = **weight** of vehicles that travel route *i*, is calculated from the following:

$$W_i = \frac{V_i}{V_{total}} = \frac{V_i}{\sum_{i=1 \text{ to } N} V_i} \tag{47}$$

We can now calculate the average travel distance, time, and speed from the following equations:

$$L_{average} = \frac{L_{total}}{V_{total}} = \frac{\sum\limits_{i=1 \text{ to } N} V_i L_i}{\sum\limits_{i=1 \text{ to } N} V_i} = \sum_{i=1 \text{ to } N} W_i L_i \qquad ((48)$$

$$T_{average} = \frac{T_{total}}{V_{total}} = \frac{\sum\limits_{i=1 \text{ to } N} V_i \frac{L_i}{S_i}}{\sum\limits_{i=1 \text{ to } N} V_i} = \sum_{i=1 \text{ to } N} W_i T_i = \sum_{i=1 \text{ to } N} W_i \frac{L_i}{S_i} \qquad (49)$$

$$S_{average} = \frac{L_{total}}{T_{total}} = \frac{\sum\limits_{i=1 \text{ to } N} V_i L_i}{\sum\limits_{i=1 \text{ to } N} V_i \frac{L_i}{S_i}} = \frac{L_{average}}{T_{average}} = \frac{\sum\limits_{i=1 \text{ to } N} W_i L_i}{\sum\limits_{i=1 \text{ to } N} W_i \frac{L_i}{S_i}} \qquad (50)$$

Note the following inequality:

$$S_{average} \neq \sum_{i=1 \text{ to } N} W_i S_i = \sum_{i=1 \text{ to } N} W_i \frac{L_i}{T_i} \qquad (51)$$

3.1.4 ROUTES SHEET (ROUTES TAB) CALCULATIONS

3.1.4.1 Routes Sheet (routes tab)

Calculation of route properties is automated in the Routes Sheet of CO^3, of which Fig. 3-2 is an example. The Routes Sheet is also explained in Sec. **1.5.2, pg. 1-15**. It consists of two tables or views:[7]

- **Route Distance, Speed, and Time** table or view, which is also called the **Route Travel** table or view for short, calculates travel distance, speed, and time that is equivalent to a group of routes.
- **Route User Costs** view calculates the individual vehicle user costs for work zone and diversion routes.

3.1.4.2 One Diversion Path with Unequal Speeds

Fig. 3-1 shows a map on which the normal route is Main Street and a single diversion route consists of Oak, Second, and Elm. The **work zone method route** = **work zone normal route** = ab = 1.5 mi. From Eq. (24) we can calculate the **diversion method route** = 1 + 3 + 1 = 5 mi along Oak, Second, and Elm. The **diversion normal route** = 3 mi = the normal route that will

[7] In the examples in this chapter, the Route Distance, Speed, and Time table is above the Route User Costs table, which is the reverse of the actual orientation of the Routes Sheet. The reason for the normal order of tables is to allow easy Copy and Paste to create additional Route Travel tables at the end of the Route Sheet. We have reversed the order here, to focus on the actual order of inputting data into the Route Distance, Speed, and Time table first. Then we use the values in the Route User Costs table (or in the Input Sheet and Traffic Sheet).

be traveled in place of the diversion route. Fig. 3-2 shows the Routes Sheet for routes in Fig. 3-1. The Route Travel table shows input and calculation of route properties for the diversion normal route and diversion method route. The diversion normal route consists of Main for 3 mi at 55 MPH, which takes 3.27 min. The three streets of the diversion method route total 5 mi at an average speed of 35.71 mph, which takes 8.40 min. By Eq. (30), **diversion delay** = 8.40 – 3.27 = 5.13 min, for the greater length = 5 – 3 = 2 mi at a speed slower by 55 – 35.71 = 19.29 mph.

The Route User Costs table in Fig. 3-2 shows input of route distance and speed and output of travel times and user costs for the routes. All Route User Costs input can be taken directly from Fig. 3-1 except for the diversion method route, for which we input the travel distance and speed output from the Route Travel table. The user cost calculations on the Route Sheet are the same as in the Input Sheet. For example, Fig. 3-3 shows a portion of an Input Sheet into which we have input the same distance, speed, and speed delay values as in Fig. 3-2. We see in Fig. 3-3 the same variables and output as in Fig. 3-2. Therefore, we generally use the Route Sheet only to calculate the equivalent route for complex routes. We then input the equivalent route distance, speed, and speed delay values into either the Route Sheet or the Input Sheet and calculate route user costs.

3.1.4.3 Two Equal Diversion Paths, Unequal Speeds

Fig. 3-4 shows two alternative diversion routes for the same normal route as in Fig. 3-1. 40% of diverted traffic has been estimated to divert to Second Street and 60% to First Street. These percentages are entered in **% that take route** = W_i in the Fig. 3-5 Routes Travel table which calculates the equivalent or average diversion method route = 5.0 mi at 36.76 mph taking 8.16 min, which is +2.0 mi, -18.24 MPH, and +4.89 min compared to the 3 mi normal method route. We entered the diversion method distance and speed into the Route User Costs table, which calculated the travel and user cost values shown. Note that we have input two sets of route input into Fig. 3-5, the second of which includes range speed delay input. This demonstrates that we can use the Route Sheet for both threshold travel and range travel.

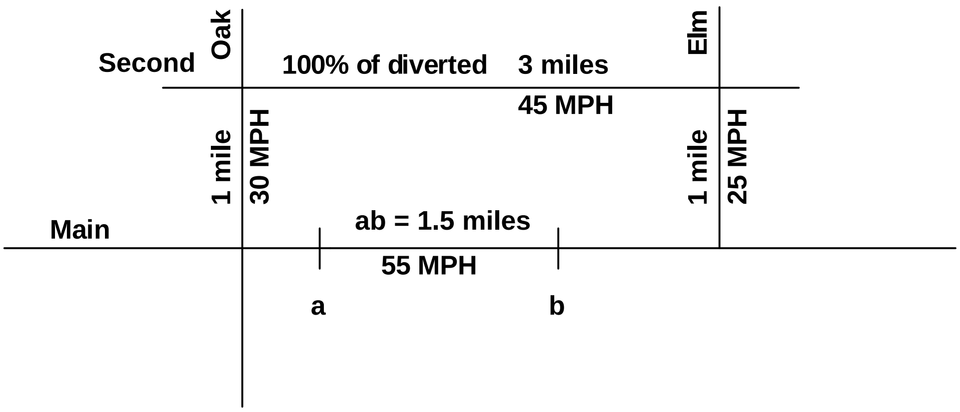

Fig. 3-1 Map for One Diversion Path with Unequal Speeds

ROUTE DISTANCE, SPEED, AND TIME — Route Title: Second St: Diversion Travel

Normal Travel							Method Travel						
Input				Calculated Values			Input				Calculated Values		
Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)	Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)
Main	100%	3	55	3.27	3	3.27	Oak	100%	1	30	2.00	1	2.00
							Second	100%	3	45	4.00	3	4.00
							Elm	100%	1	25	2.40	1	2.40
Totals	1.00				3.00	3.27	Totals	3.00				5.00	8.40
Averages		3.00	55.00	3.27			Averages		5.00	35.71	8.40		
							Differences		2.00	-19.29	5.13		

ROUTE USER COSTS

VEHICLE INPUT	cars	trucks
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00

ROUTE TITLES		Second St							
DISTANCE AND SPEED INPUT	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	1.5	see delay		see delay		see delay		see delay
	normal travel	1.5	55						
diversion	method travel	5.0	35.7						
	normal travel	3.0	55						
SPEED DELAY INPUT		threshold	range	threshold	range	threshold	range	threshold	range
capacity for speed delay (V/hr)									
speed (when D~0) (mph)		45							
speed (when D=C) (mph)		25							
WORK ZONE TRAVEL									
zone normal travel time (min)		1.64							
zone method travel time (when D~0) (min)		2.00							
speed delay (when D~0) (min)		0.36							
zone method travel time (when D=C) (min)		3.60							
speed delay (when D=C) (min)		1.96							
WORK ZONE USER COST		threshold	range	threshold	range	threshold	range	threshold	range
car speed delay user cost (when D~0)		$0.07							
truck speed delay user cost (when D~0)		$0.07							
car speed delay user cost (when D=C)		$0.35							
truck speed delay user cost (when D=C)		$0.35							
DIVERSION TRAVEL									
diversion method travel time (min)		8.40							
diversion normal travel time (min)		3.27							
diversion delay (min)		5.13							
extra diversion travel distance (mi)		2.0							
DIVERSION USER COST		cars	trucks	cars	trucks	cars	trucks	cars	trucks
diversion delay user cost		$0.92	$0.92						
diversion distance user cost		$0.60	$2.00						
diversion user cost		$1.52	$2.92						
backup delay balance (min)		6.50	14.29						

Fig. 3-2 Routes Sheet for One Diversion Path with Unequal Speeds

PROJECT INPUT AND DOCUMENTATION	Project:		
	By:		
	Other:		
METHOD INPUT	METHOD #		
method title			
VEHICLE INPUT		cars	trucks
1	design demand (%)		
0	user cost per hour ($/V hr)	$10.79	$10.79
0	user cost per mile, ($/V mi)	$0.30	$1.00
4	user cost per cancellation, ($/V)		
ROUTE TITLES		Standard	
DISTANCE AND SPEED INPUT		distance	speed
1	work zone method travel	1.5	see delay
1	work zone normal travel	1.5	55
1	diversion method travel	5.0	35.7
1	diversion normal travel	3.0	55
SPEED DELAY INPUT		threshold	range
2	capacity for speed delay (V/hr)		
3	speed (when D~0) (mph)	45	
3	speed (when D=C) (mph)	25	
WORK ZONE TRAVEL		threshold	range
	normal travel time (min)	1.64	
	method travel time (when D~0) (min)	2.00	
	speed delay (when D~0) (min)	0.36	
	method travel time (when D=C) (min)	3.60	
	speed delay (when D=C) (min)	1.96	
WORK ZONE SPEED DELAY USER COST		threshold	range
	car speed delay user cost (when D~0)	$0.07	
	truck speed delay user cost (when D~0)	$0.07	
	car speed delay user cost (when D=C)	$0.35	
	truck speed delay user cost (when D=C)	$0.35	
DIVERSION TRAVEL			
	method travel time (min)	8.40	
	normal travel time (min)	3.27	
	diversion delay (min)	5.13	
	extra diversion travel distance (mi)	2.0	
DIVERSION USER COST		cars	trucks
	diversion delay user cost	$0.92	$0.92
	diversion distance user cost	$0.60	$2.00
	diversion user cost	$1.52	$2.92
	backup delay balance (min)	6.50	14.29

Fig. 3-3 Portion of Input Sheet for One Diversion Path with Unequal Speeds (see Fig. 3-2)

3.1.4.4 Two Unequal Diversion Paths, Unequal Speeds

Fig. 3-6 (which is the same as Fig. 1-4, pg. 1-18) shows two alternative diversion routes of different length, each of which has a different normal route. Of the traffic that diverts, 40% diverts to Oak-Second-Elm = 5 mi instead of traveling 3 mi on Main and 60% diverts to Oak-First-Elm = 6 mi instead of traveling 4 mi on Main. The Fig. 3-7 Route Travel table calculates the equivalent or average normal route (on Main) = 3.6 mi at 55.0 MPH taking 3.93 min and equivalent or average diversion is 5.6 mi at 40.29 MPH taking 8.34 min. This is +2.0 mi, -14.71 mph, and +4.74 min compared to the normal route. The Fig. 3-7 Route User Cost table calculates travel times and delays and user costs for the equivalent route, which are the same as we would calculate in an Input Sheet.

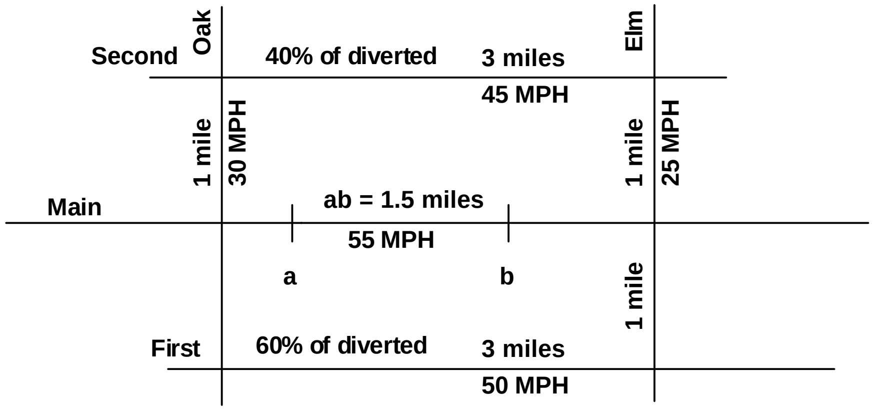

Fig. 3-4 Map for Two Equal Diversion Paths with Unequal Speeds

ROUTE DISTANCE, SPEED, AND TIME

Route Title:							First & Second: Diversion Travel						
Normal Travel							Method Travel						
Input				Calculated Values			Input				Calculated Values		
Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)	Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)
Main	100%	3	55	3.27	3	3.27	N. Oak	40%	1	30	2.00	0.4	0.80
							Second	40%	3	45	4.00	1.2	1.60
							Elm	40%	1	25	2.40	0.4	0.96
							S. Oak	60%	1	30	2.00	0.6	1.20
							First	60%	3	50	3.60	1.8	2.16
							Elm	60%	1	25	2.40	0.6	1.44
Totals	1.00				3.00	3.27	Totals	3.00				5.00	8.16
Averages		3.00	55.00	3.27			Averages		5.00	36.76	8.16		
							Differences		2.00	-18.24	4.89		

ROUTE USER COSTS

VEHICLE INPUT	cars	trucks
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00

ROUTE TITLES		First & Second		With Range Capacity					
DISTANCE AND SPEED INPUT	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	1.5	see delay	1.5	see delay		see delay		see delay
	normal travel	1.5	55	1.5	55				
diversion	method travel	5.0	36.8	5.0	36.8				
	normal travel	3.0	55	3.0	55				
SPEED DELAY INPUT		threshold	range	threshold	range	threshold	range	threshold	range
	capacity for speed delay (V/hr)								
	speed (when D~0) (mph)	45		45	40				
	speed (when D=C) (mph)	25		25	15				
WORK ZONE TRAVEL									
	zone normal travel time (min)	1.64		1.64	1.64				
	zone method travel time (when D~0) (min)	2.00		2.00	2.25				
	speed delay (when D~0) (min)	0.36		0.36	0.61				
	zone method travel time (when D=C) (min)	3.60		3.60	6.00				
	speed delay (when D=C) (min)	1.96		1.96	4.36				
WORK ZONE USER COST		threshold	range	threshold	range	threshold	range	threshold	range
	car speed delay user cost (when D~0)	$0.07		$0.07	$0.11				
	truck speed delay user cost (when D~0)	$0.07		$0.07	$0.11				
	car speed delay user cost (when D=C)	$0.35		$0.35	$0.78				
	truck speed delay user cost (when D=C)	$0.35		$0.35	$0.78				
DIVERSION TRAVEL									
	diversion method travel time (min)	8.16		8.16					
	diversion normal travel time (min)	3.27		3.27					
	diversion delay (min)	4.89		4.89					
	extra diversion travel distance (mi)	2.0		2.0					
DIVERSION USER COST		cars	trucks	cars	trucks	cars	trucks	cars	trucks
	diversion delay user cost	$0.88	$0.88	$0.88	$0.88				
	diversion distance user cost	$0.60	$2.00	$0.60	$2.00				
	diversion user cost	$1.48	$2.88	$1.48	$2.88				
	backup delay balance (min)	6.26	14.05	6.26	14.05				

Fig. 3-5 Routes Sheet for Two Equal Diversion Paths with Unequal Speeds

3.1.4.5 Two Normal Paths and Two Diversion Paths

Fig. 3-8 shows two normal routes that share different portions of work zone FG. At the AF fork of G, 30% take A and 70% take F. Diverted traffic has alternative routes, of which 25%

take B, 50% take KH, and 25% take KJD. The first Fig. 3-9 tables both show **equivalent normal route for calculating speed delay** = 4.40 mi at 45.52 MPH taking 5.80 min. The "Work Zone Travel when D ~ 0" table shows **method travel speed (when D ~ 0)** = 32.20 MPH. The "Work Zone Travel when *D ³ C*" table shows **method travel time (when D ≥ C)** = 15.17 MPH. The "Diverted Traffic" table shows the **equivalent normal route for diversions** = 8.25 mi at 47.03 MPH taking 10.52 min, and the **equivalent diversion route** = 10.5 mi at 34.05 MPH taking 18.50 min. This is +2.25 mi, -12.98 MPH, and +7.97 min compared to the normal route. Fig. 3-10 shows travel times and delays and user costs for the equivalent route, which are the same as we would calculate in an Input Sheet.

3.1.4.6 Two Normal Paths and Two Diversion Paths, Truck Diversion ¹ Car Diversion

Fig. 3-11 is the same as Fig. 3-8, except that trucks are not allowed to take B or J. Therefore, no trucks can divert from AG, and all trucks that divert from DEFG must take HK. Therefore, 100% of diverted trucks take HK. Fig. 3-12 calculates equivalent routes. Its first two tables are the same as the first two tables in Fig. 3-9. However, diverted cars and diverted cars have different equivalent routes, which are calculated in the second two tables. The equivalent routes for diverted cars is shown in the third table of Fig. 3-12, which is the same as the equivalent diversion route for all traffic in Fig. 3-9. The "Diverted Trucks" table (the fourth table) shows the diversion normal route for trucks is CDEFG, because all trucks that divert would normally have taken this route. This **equivalent normal truck route for diversions** = 8 mi at 47.06 MPH taking 10.20 min. The **equivalent truck diversion route** = 11 mi at 33.00 MPH taking 20 min, which is +3.00 mi, -14.06 MPH, and 9.80 min more than the normal route. Fig. 3-13 shows travel times and delays and user costs for the equivalent route, which are the same as we would calculate in an Input Sheet.

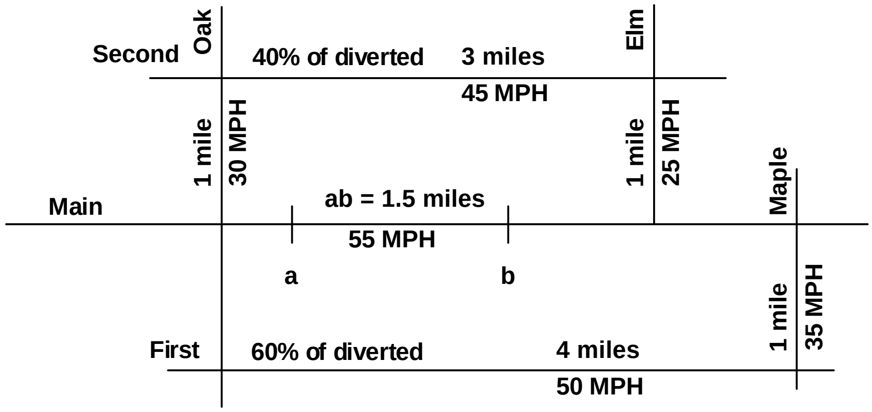

Fig. 3-6 Map for Two Unequal Diversion Paths

ROUTE DISTANCE, SPEED, AND TIME — Route Title: First & Second: Diversion Travel

Normal Travel							Method Travel						
Input				Calculated Values			Input				Calculated Values		
Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)	Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)
Main	40%	3	55	3.27	1.2	1.31	N. Oak	40%	1	30	2.00	0.4	0.80
Main	60%	4	55	4.36	2.4	2.62	Second	40%	3	45	4.00	1.2	1.60
							Elm	40%	1	25	2.40	0.4	0.96
							S. Oak	60%	1	30	2.00	0.6	1.20
							First	60%	4	50	4.80	2.4	2.88
							Maple	60%	1	40	1.50	0.6	0.90
Totals	1.00				3.60	3.93	Totals	3.00				5.60	8.34
Averages		3.60	55.00	3.93			Averages		5.60	40.29	8.34		
							Differences		2.00	-14.71	4.41		

ROUTE USER COSTS

VEHICLE INPUT	cars	trucks
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00

ROUTE TITLES		First & Second							
DISTANCE AND SPEED INPUT	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	1.5	see delay		see delay		see delay		see delay
	normal travel	1.5	55						
diversion	method travel	5.6	40.3						
	normal travel	3.6	55						
SPEED DELAY INPUT		threshold	range	threshold	range	threshold	range	threshold	range
capacity for speed delay (V/hr)									
speed (when D~0) (mph)		45							
speed (when D=C) (mph)		25							
WORK ZONE TRAVEL									
zone normal travel time (min)		1.64							
zone method travel time (when D~0) (min)		2.00							
speed delay (when D~0) (min)		0.36							
zone method travel time (when D=C) (min)		3.60							
speed delay (when D=C) (min)		1.96							
WORK ZONE USER COST		threshold	range	threshold	range	threshold	range	threshold	range
car speed delay user cost (when D~0)		$0.07							
truck speed delay user cost (when D~0)		$0.07							
car speed delay user cost (when D=C)		$0.35							
truck speed delay user cost (when D=C)		$0.35							
DIVERSION TRAVEL									
diversion method travel time (min)		8.34							
diversion normal travel time (min)		3.93							
diversion delay (min)		4.41							
extra diversion travel distance (mi)		2.0							
DIVERSION USER COST		cars	trucks	cars	trucks	cars	trucks	cars	trucks
diversion delay user cost		$0.79	$0.79						
diversion distance user cost		$0.60	$2.00						
diversion user cost		$1.39	$2.79						
backup delay balance (min)		5.79	13.57						

Fig. 3-7 Routes Sheet for Two Unequal Diversion Paths

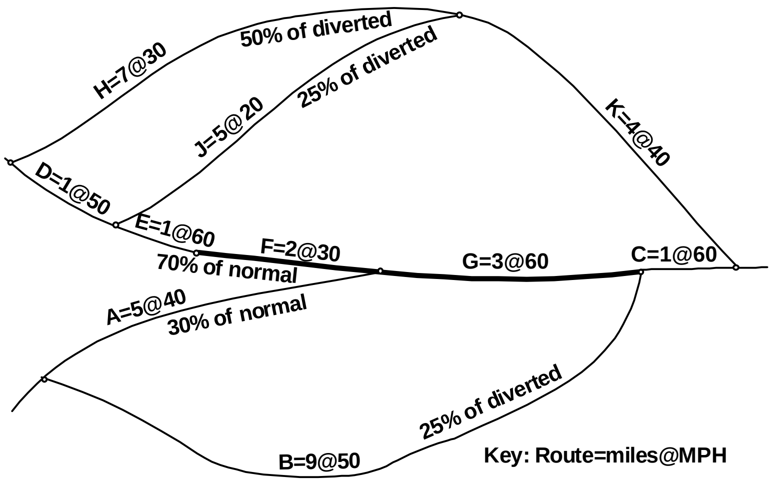

Fig. 3-8 Map for Multiple Normal and Diversion Paths

ROUTE DISTANCE, SPEED, AND TIME						Route Title:	Work Zone Travel when D ~ 0						
Normal Travel							Method Travel						
Input				Calculated Values			Input				Calculated Values		
Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)	Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)
F	70%	2	30	4.00	1.4	2.80	F	70%	2	20	6.00	1.4	4.20
G	100%	3	60	3.00	3	3.00	G	100%	3	45	4.00	3	4.00
Totals	1.70				4.40	5.80	Totals	1.70				4.40	8.20
Averages		4.4	45.52	5.80			Averages		4.4	32.20	8.20		
							Differences			-13.32	2.40		

ROUTE DISTANCE, SPEED, AND TIME						Route Title:	Work Zone Travel when D ≥ C						
Normal Travel							Method Travel						
Input				Calculated Values			Input				Calculated Values		
Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)	Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)
F	70%	2	30	4.00	1.4	2.80	F	70%	2	10	12.00	1.4	8.40
G	100%	3	60	3.00	3	3.00	G	100%	3	20	9.00	3	9.00
Totals	1.70				4.40	5.80	Totals	1.70				4.40	17.40
Averages		4.4	45.52	5.80			Averages		4.4	15.17	17.40		
							Differences			-30.34	11.60		

ROUTE DISTANCE, SPEED, AND TIME						Route Title:	Diverted Traffic						
Normal Travel							Method Travel						
Input				Calculated Values			Input				Calculated Values		
Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)	Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)
A	25%	5	40	7.50	1.25	1.87	B	25%	9	50	10.80	2.25	2.70
C	100%	1	60	1.00	1.00	1.00	C	25%	1	60	1.00	0.25	0.25
D	75%	1	50	1.20	0.75	0.90							
E	75%	1	60	1.00	0.75	0.75	D	25%	1	50	1.20	0.25	0.30
F	75%	2	30	4.00	1.50	3.00	H	50%	7	30	14.00	3.50	7.00
G	100%	3	60	3.00	3.00	3.00	J	25%	5	20	15.00	1.25	3.75
							K	75%	4	40	6.00	3.00	4.50
Totals	4.50				8.25	10.52	Totals	2.25				10.50	18.50
Averages		8.25	47.03	10.52			Averages		10.50	34.05	18.50		
							Differences		2.25	-12.98	7.97		

Fig. 3-9 Route Travel for Multiple Normal and Diversion Paths

ROUTE USER COSTS

VEHICLE INPUT	cars	trucks
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00

ROUTE TITLES		Standard							
DISTANCE AND SPEED INPUT	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	4.40	see delay		see delay		see delay		see delay
	normal travel	4.40	45.52						
diversion	method travel	10.00	34.29						
	normal travel	8.25	47.29						
SPEED DELAY INPUT		threshold	range	threshold	range	threshold	range	threshold	range
capacity for speed delay (V/hr)									
speed (when D~0) (mph)		32.20							
speed (when D=C) (mph)		15.17							
WORK ZONE TRAVEL									
zone normal travel time (min)		5.80							
zone method travel time (when D~0) (min)		8.20							
speed delay (when D~0) (min)		2.40							
zone method travel time (when D=C) (min)		17.40							
speed delay (when D=C) (min)		11.60							
WORK ZONE USER COST		threshold	range	threshold	range	threshold	range	threshold	range
car speed delay user cost (when D~0)		$0.43							
truck speed delay user cost (when D~0)		$0.43							
car speed delay user cost (when D=C)		$2.09							
truck speed delay user cost (when D=C)		$2.09							
DIVERSION TRAVEL									
diversion method travel time (min)		17.50							
diversion normal travel time (min)		10.47							
diversion delay (min)		7.03							
extra diversion travel distance (mi)		1.8							
DIVERSION USER COST		cars	trucks	cars	trucks	cars	trucks	cars	trucks
diversion delay user cost		$1.26	$1.26						
diversion distance user cost		$0.53	$1.75						
diversion user cost		$1.79	$3.01						
backup delay balance (min)		-1.65	5.16						

Fig. 3-10 Route User Costs for Multiple Normal and Diversion Paths

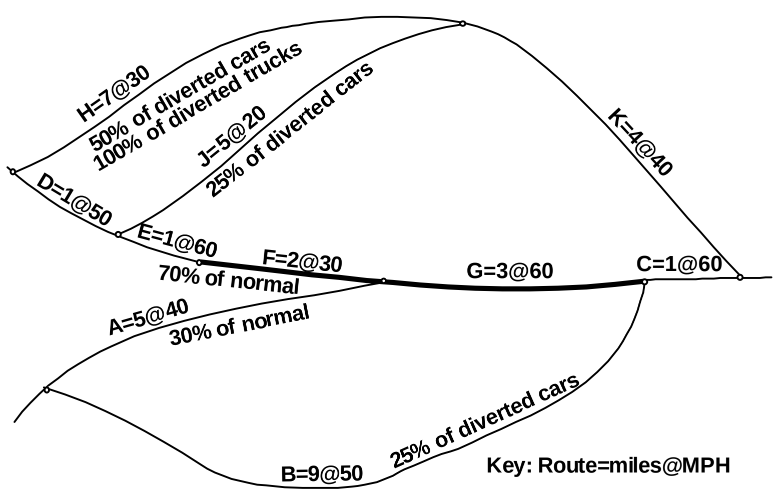

Fig. 3-11 Map for Multiple Paths and Different Car and Truck Diversions

ROUTE DISTANCE, SPEED, AND TIME Route Title: Work Zone Travel when D ~ 0

Normal Travel							Method Travel						
Input				Calculated Values			Input				Calculated Values		
Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)	Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)
F	70%	2	30	4.00	1.4	2.80	F	70%	2	20	6.00	1.4	4.20
G	100%	3	60	3.00	3	3.00	G	100%	3	45	4.00	3	4.00
Totals	1.70				4.40	5.80	Totals	1.70				4.40	8.20
Averages		4.4	45.52	5.80			Averages		4.4	32.20	8.20		
							Differences			-13.32	2.40		

ROUTE DISTANCE, SPEED, AND TIME Route Title: Work Zone Travel when D ≥ C

Normal Travel							Method Travel						
Input				Calculated Values			Input				Calculated Values		
Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)	Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)
F	70%	2	30	4.00	1.4	2.80	F	70%	2	10	12.00	1.4	8.40
G	100%	3	60	3.00	3	3.00	G	100%	3	20	9.00	3	9.00
Totals	1.70				4.40	5.80	Totals	1.70				4.40	17.40
Averages		4.4	45.52	5.80			Averages		4.4	15.17	17.40		
							Differences			-30.34	11.60		

ROUTE DISTANCE, SPEED, AND TIME Route Title: Diverted Cars

Normal Travel							Method Travel						
Input				Calculated Values			Input				Calculated Values		
Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)	Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)
A	25%	5	40	7.50	1.25	1.87	B	25%	9	50	10.80	2.25	2.70
C	100%	1	60	1.00	1.00	1.00	C	25%	1	60	1.00	0.25	0.25
D	75%	1	50	1.20	0.75	0.90							
E	75%	1	60	1.00	0.75	0.75	D	25%	1	50	1.20	0.25	0.30
F	75%	2	30	4.00	1.50	3.00	H	50%	7	30	14.00	3.50	7.00
G	100%	3	60	3.00	3.00	3.00	J	25%	5	20	15.00	1.25	3.75
Totals	4.50				8.25	10.52	Totals	2.25				10.50	18.50
Averages		8.25	47.03	10.52			Averages		10.50	34.05	18.50		
							Differences		2.25	-12.98	7.97		

ROUTE DISTANCE, SPEED, AND TIME Route Title: Diverted Trucks

Normal Travel							Method Travel						
Input				Calculated Values			Input				Calculated Values		
Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)	Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)
A		5	40	7.50			B		9	50	10.80		
C	100%	1	60	1.00	1.00	1.00	C		1	60	1.00		
D	100%	1	50	1.20	1.00	1.20							
E	100%	1	60	1.00	1.00	1.00	D		1	50	1.20		
F	100%	2	30	4.00	2.00	4.00	H	100%	7	30	14.00	7.00	14.00
G	100%	3	60	3.00	3.00	3.00	J		5	20	15.00		
							K	100%	4	40	6.00	4.00	6.00
Totals	5.00				8.00	10.20	Totals	2.00				11.00	20.00
Averages		8.00	47.06	10.20			Averages		11.00	33.00	20.00		
							Differences		3.00	-14.06	9.80		

Fig. 3-12 Route Travel for Multiple Paths, Different Car and Truck Diversions

ROUTE USER COSTS

VEHICLE INPUT		cars	trucks						
user cost per hour ($/V hr)		$10.79	$10.79						
user cost per mile, ($/V mi)		$0.30	$1.00						
ROUTE TITLES		Cars		Trucks					
DISTANCE AND SPEED INPUT	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	4.40	see delay	4.40	see delay		see delay		see delay
	normal travel	4.40	45.52	4.40	45.52				
diversion	method travel	10.50	34.05	11.00	33.00				
	normal travel	8.25	47.03	8.00	47.06				
SPEED DELAY INPUT		threshold	range	threshold	range	threshold	range	threshold	range
capacity for speed delay (V/hr)									
speed (when D~0) (mph)		32.20		32.20					
speed (when D=C) (mph)		15.17		15.17					
WORK ZONE TRAVEL									
zone normal travel time (min)		5.80		5.80					
zone method travel time (when D~0) (min)		8.20		8.20					
speed delay (when D~0) (min)		2.40		2.40					
zone method travel time (when D=C) (min)		17.40		17.40					
speed delay (when D=C) (min)		11.60		11.60					
WORK ZONE USER COST		threshold	range	threshold	range	threshold	range	threshold	range
car speed delay user cost (when D~0)		$0.43		$0.43					
truck speed delay user cost (when D~0)		$0.43		$0.43					
car speed delay user cost (when D=C)		$2.09		$2.09					
truck speed delay user cost (when D=C)		$2.09		$2.09					
DIVERSION TRAVEL									
diversion method travel time (min)		18.50		20.00					
diversion normal travel time (min)		10.53		10.20					
diversion delay (min)		7.98		9.80					
extra diversion travel distance (mi)		2.3		3.0					
DIVERSION USER COST		cars	trucks	cars	trucks	cars	trucks	cars	trucks
diversion delay user cost		$1.43	$1.43	$1.76	$1.76				
diversion distance user cost		$0.68	$2.25	$0.90	$3.00				
diversion user cost		$2.11	$3.68	$2.66	$4.76				
backup delay balance (min)		0.13	8.89	3.20	14.88				

Fig. 3-13 Route User Costs for Multiple Paths, Different Car and Truck Diversions

3.2 ZONE AND DIVERSION USER COSTS

3.2.1 INTRODUCTION

User costs for travel through the work zone and for diversion around the work zone are calculated from route distance and speed information. These are input into the “Route User Cost” table portion of a “routes” worksheet. Input can be taken from the “Route Distance, Speed, and Time” table output, or it can be calculated separately.

3.2.2 DISTANCE AND SPEED INPUTS

Distance and speed for work zone method travel and work zone normal travel are most typically direct estimates for the work zone. For example, Fig. 3-1, pg. 3-5 shows work zone distance on Main Street = ab = 1.5 mi = work zone method travel distance = work zone normal travel distance. Normal traffic speed on Main is estimated to be 55 MPH, so work zone normal travel speed = 55 MPH. We estimated that during construction [that is, for $C \leq$(threshold capacity for speed delay)] when traffic is light (for demand = $D \approx 0$) work zone speed = 45 MPH and when traffic is heavy (for demand = $D \geq C$) work zone speed = 25 MPH.

The diversion delay routes are different from the work zone routes. We first identify the diversion route(s) and then we identify the corresponding normal route(s) taken by vehicles that do not divert. Fig. 3-1 shows the diversion route around work zone ab is Oak, Second, and Elm whose distances sum to diversion method travel distance = 5.0 mi. Because these three streets have different traffic speeds, **diversion method travel speed** = 35.71 MPH was calculated as described above. The comparable normal route traveled by vehicles that do not divert is diversion normal travel distance = 3 mi on Main Street at **diversion normal travel speed** = 55 MPH. Input for calculation of Route User Costs is now complete.

3.2.3 TRAVEL CALCULATIONS

Work Zone Travel calculations follow the equations above. Normal travel time is calculated using Eq. (24) for work zone ab, as are method travel time (when $D \approx 0$) and method travel time (when $D \geq C$), based on the appropriate speed inputs. For example, for Fig. 3-2, zone normal travel time = (1.5 mi) * (60 min/hr) / (55 MPH) = 1.64 min. Speed delays are calculated using Eq. (28).[8] For example, for Fig. 3-2, speed delay (when $D \approx 0$) = 2.00 - 1.64 = 0.36 min. Diversion delay calculations parallel speed delay calculations, using appropriate diversion distance and speed input.

Work Zone Travel in Fig. 3-5, for "First & Second" columns is the same as for Fig. 3-2. However, the next columns, for "With Range Capacity," demonstrate input and calculations when there is a **range capacity for speed delay**, which is indicated by of (range speed (when D~0) ≠ 0 and range speed (when $D=C$) ≠ 0.

The distance that vehicles travel through the work zone during work is usually the same as under normal conditions, except when there is a detour. Therefore, extra zone travel distance = 0, unless there is a detour. For this reason, the "routes" worksheet does not show extra zone travel distance. However, diversion routes usually require

$$\text{extra diversion travel distance} = (\text{diversion method travel distance}) - (\text{diversion normal travel distance}) \quad (52)$$

For example, for Fig. 3-2, extra diversion travel distance = 5.0 - 3.0 = 2.0 mi.

3.2.4 USER COST CALCULATIONS

User cost per vehicle is calculated using the following equations.

$$\text{delay user cost} = \left[\text{delay (hr)}\right] * \left[\text{user cost per hour (\$ / V - hr)}\right] \quad (53)$$

$$\text{distance user cost} = \left[\text{distance (mi)}\right] * \left[\text{user cost per mile (\$ / mi)}\right] \quad (54)$$

$$\text{user cost} = \text{delay user cost} + \text{distance user cost} \quad (55)$$

For example, for Fig. 3-2, **car diversion delay user cost** = (diversion delay) * (car user cost per hour) = [(5.13 min) / (60 min/hr)] * ($10.79 / hr) = $0.92. **Car diversion distance user cost** = (extra diversion travel distance) * (car user cost per mile) = (2.0 mi) * ($0.30 / hr) = $0.60. Car diversion user cost = 0.92 + 0.60 = $1.52. Work zone speed delay user cost is calculated similarly. Backup delay user cost also follows Eq. (27). It is not shown in the worksheet, because

---

[8] In some instances, the spreadsheet may show a "blank" for some values, when the correct value is 0. This happens particularly for *speed delay* = 0 and *speed delay user cost* = 0, when *work zone normal travel speed* = *threshold speed* (*when D » 0*). The "blank" in place of zero occurs when the spreadsheet is configured to show zero as "blank." To change this, with your mouse click on "Tools" in the toolbar at the top of the spreadsheet. In the "Tools" menu that results, click "Options." In the "Options" window that results, click "View." In the "View" window that results, click "Zero values" such that it shows a check mark (✓) to its left. Then click on "OK." This will make the spreadsheet show zero, rather than showing zero as "blank."

backup delay is not known at this point. A useful variable that can be calculated is backup delay balance, which is the magnitude of backup delay at which the (zone user cost) = (speed delay user cost) + (backup delay user cost) = (diversion user cost). This is calculated using

$$\text{backup delay balance (min)} = \frac{[\text{diversion user cost (\$)}] - [\text{speed delay user cost (\$)}]}{[\text{user cost per hour (\$ / hr)}] * [60 \text{ (min / hr)}]} \quad (56)$$

The worksheet calculates backup delay balance for work zone speed delay user cost (when $D=C$) for the threshold capacity for speed delay. For example, Fig. 3-2 shows **car backup delay balance** = (1.52 - 0.35) / (10.79/60) = 6.50 min. Thus, for this demand and capacity, (diversion user cost) = (zone user cost) for cars when backup delay = 6.50 min.

Though the “routes” worksheet does not show extra zone travel distance, any difference between zone method travel distance and zone normal travel distance is considered in calculating zone user cost.

3.2.5 RELATIONSHIP AMONG TABLES AND WORKSHEETS

Route Distance, Speed, and Time table and Route User Cost table input, calculations, and output are not internally connected. In fact, they are independent, because input to both tables is manual. That is, (1) changes in the “Route Distance, Speed, and Time” table impact its values, but they are not transmitted internally to Route User Cost input. Therefore, we must separately input changes to routes in both tables. This may seem cumbersome, but it allows for independent calculation of values.

Similarly, both tables calculate some of the same values. For example, “Route Distance, Speed, and Time” calculates normal travel values, method travel values, and the differences between the two sets of values. Some but not all of this is also calculated in Route User Cost. Therefore, each can be considered independently. For example, for many projects, there is no need to calculate Route Distance, Speed, and Time,”because the routes are simple enough that we can estimate the overall distance and speed of each. We can enter the estimated values directly into Route User Cost and review its output to understand delays and user costs. (Actually, in most of these cases we will use the Input Sheet without using the Routes Sheet.)

Similarly, Routes Sheets are not connected to an Input Sheet or a Traffic Sheet. Instead, the route input for all is the same, which allows one to copy input values from one to the other. Each calculates the same values. Of course, the Traffic Sheet does not show all the calculated values of Route User Cost table or the Input Sheet, because its space is reserved for other CO^3 input and output.

Occasional projects, such as in Fig. 3-13, may have different diversion fractions for cars and trucks. We entered route information from the “Diverted Cars” table into Route User Costs under “Cars,” and from the “Diverted Trucks” table into Route User Costs under “Trucks.” Under “Cars,” Route User Costs computes values for cars and trucks as if both used the ”Diverted Cars” route, and under “Trucks,” Route User Costs computes values for cars and trucks as if both used the “Diverted Trucks” route.

Of course, in this example, diverted cars and trucks do not use the same route. Therefore, for “Diversion Travel” and “Diversion User Cost,” the values under “Cars” applies only to cars, and the values under “Trucks” applies only to trucks. The diversion values of “Cars” have no meaning for trucks and the diversion values of “Trucks” have no meaning for cars. To calculate diverted traffic costs in CO^3 we can take the cars diversion user cost from “Cars” and the trucks diversion user cost from “Trucks” and enter them in the Summary View of the Traffic Sheet in user cost per diversion. The Overall View of the Traffic Sheet will then use these input values for its user cost calculations. For example, from Fig. 3-13 calculations we can input car diversion user cost = $2.11 and truck diversion user cost = $4.76 in place of the equations in the user cost per diversion cells near the center of the Summary View in a Traffic Sheet. These values then will be used in calculating user cost of decreases by CO^3.

3.3 FLAG ROUTES SHEET (FLAG ROUTES TAB)

The Flag Routes Sheet parallels the Routes Sheet in the COFlag.xls Program for calculating route values for flagging operations. The Flag Routes Sheet also parallels the Flag Input Sheet in the same way the Routes Sheet parallels the Input Sheet. Eq. (27) to (51) apply to the “flag routes” worksheet for calculation of equivalent route travel distances, speeds, and times. Eq. (52) to (55) apply to Flag Routes user cost calculations. However, the Routes Sheet and Flag Routes Sheet differ in some variables: Flag Routes has variables associated with gate activities and it does not have threshold and range variables of Routes. The impacts of flagging operation gate variables are described below. They are demonstrated in Fig. 3-14 for the routes in Fig. 3-1. We see that the Route Distance, Speed, and Time table in Fig. 3-14 is the same as in Fig. 3-2.

In the Flag Routes Sheet, all gate delay values calculated are average gate delay for all vehicles that travel that hour, regardless of direction. Each vehicle will have a gate delay time larger or smaller than the calculated gate delay values. Minimum gate delay occurs when traffic is very light, each gate is left open only long enough to accommodate the one or two vehicles that may have accumulated while the gate was closed, and gate open time$\rightarrow$ 0. Minimum gate and speed delay occurs in conjunction with minimum gate delay.

$$\text{minimum gate delay (min)} = \left[\text{method traverse time (min)}\right] + \left[\frac{\text{dead time at gate (sec)}}{60\ (\text{sec / min})}\right] \qquad (57)$$

$$\text{minimum gate and speed delay} = (\text{minimum gate delay}) + (\text{speed delay}) \qquad (58)$$

Maximum gate delay occurs when the average gate closed time = allowable gate closed time. This limits capacity to maximum capacity. The average time interval between movements of backed-up vehicles will be allowable gate closed time. Maximum gate and speed delay occurs in conjunction with maximum gate delay.

$$\text{maximum gate delay (min)} = 0.5 * \left[\text{allowable gate closed time (min)}\right] \qquad (59)$$

$$\text{maximum gate and speed delay} = (\text{maximum gate delay}) + (\text{speed delay}) \qquad (60)$$

$$\text{maximum capacity (V / hr)} = \frac{3600\ (\text{sec / hr})}{\left[\text{headway (sec / V)}\right]} * \left[1 - \frac{(\text{minimum gate delay})}{(\text{maximum gate delay}) - (\text{minimum gate delay})}\right] \qquad (61)$$

In parallel with Eq. (56), backup delay balance for flagging is calculated from

backup delay balance (min)

$$= \frac{\left[\text{diversion user cost (\$)}\right] - \left[\text{maximum gate and speed delay user cost (\$)}\right]}{\left[\text{user cost per hour (\$ / hr)}\right] * \left[60 \text{ (min / hr)}\right]} \tag{62}$$

ROUTE DISTANCE, SPEED, AND TIME — Route Title: Second St.: Diversion Travel

Normal Travel							Method Travel						
Input				Calculated Values			Input				Calculated Values		
Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)	Route Name	% that Take Route	Distance (mi)	Speed (mph)	Travel Time (min)	Weighted Distance (mi)	Weighted Time (min)
Main	100%	3	55	3.27	3	3.27	Oak	100%	1	30	2.00	1	2.00
							Second	100%	3	45	4.00	3	4.00
							Elm	100%	1	25	2.40	1	2.40
Totals	1.00				3.00	3.27	Totals	3.00				5.00	8.40
Averages		3.00	55.00	3.27			Averages		5.00	35.71	8.40		
							Differences		2.00	-19.29	5.13		

ROUTE USER COSTS

VEHICLE INPUT	cars	trucks
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00

ROUTE INPUT		Second St							
DISTANCE AND SPEED INPUT	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	1.5	25						
	normal travel	1.5	55						
diversion	method travel	5.0	35.7						
	normal travel	3.0	55						
FLAG OPERATION INPUT									
vehicle headway at gate (sec)		3							
dead time at gate when direction changes (sec)		15							
allowable gate closed time (min.)		10							
WORK ZONE TRAVEL									
zone method traverse time (min)		3.60							
zone normal traverse time (min)		1.64							
speed delay (min)		1.96							
minimum gate delay (min)		3.85							
maximum gate delay (min)		5.00							
minimum gate and speed delay (min)		5.81							
maximum gate and speed delay (min)		6.96							
maximum capacity (V/hr)		448.8							
ZONE USER COST		cars	trucks	cars	trucks	cars	trucks	cars	trucks
minimum gate and speed delay user cost		$1.05	$1.05						
maximum gate and speed delay user cost		$1.25	$1.25						
DIVERSION TRAVEL									
diversion method travel time (min)		8.40							
diversion normal travel time (min)		3.27							
diversion delay (min)		5.13							
extra diversion travel distance (mi)		2.0							
DIVERSION USER COST		cars	trucks	cars	trucks	cars	trucks	cars	trucks
diversion delay user cost		$0.92	$0.92						
diversion distance user cost		$0.60	$2.00						
diversion user cost		$1.52	$2.92						
backup delay balance (min)		1.50	9.29						

Fig. 3-14 Routes Sheet for One Diversion Path with Unequal Speeds

CHAPTER 4

USING THE CO^{3}FLAG SYSTEM

4.1 THE CO^{3}FLAG SYSTEM

4.1.1 FLAGGING: ALTERNATING TRAFFIC IN ONE LANE

A common method of maintaining traffic through a work zone is to maintain one lane open, on which traffic alternates in direction under the control of a flagger, signal, or other control at each end. This is illustrated in Fig. 4-1, which shows two-way traffic at each end of one lane in which traffic alternates. Flagger or signal A, for example, will open the "gate" at A to admit into the zone vehicles traveling from left to right, while vehicles wait at B. A platoon of vehicles travels from A to B. At some point, gate B is closed. After all vehicles that entered at A have left at B, Gate B is opened, and vehicles waiting at B enter and traverse the zone from right to left, while vehicles wait at closed gate A.

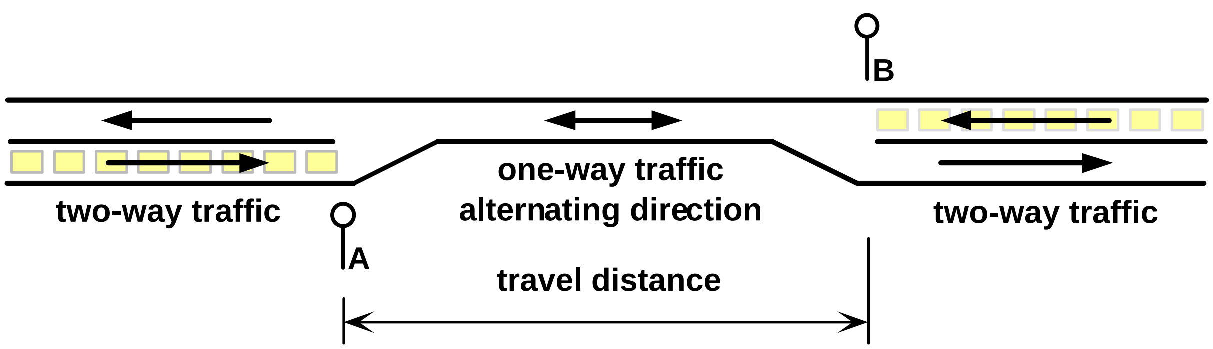

Fig. 4-1 Alternating Traffic in One lane between Controlled Gates at A and B

4.1.2 THE CO^{3}FLAG PROGRAM: COFLAG.XLS

Flagging operations have many characteristics of typical lane closures, but there are major differences. We describe the use of the CO^3 System for flagging operations in this chapter by focusing on the differences. We reference the particularly pertinent elements in the other chapters that flagging operations share with typical lane closures.

The standard CO^3 Programs are in CO.xls. The flagging CO^3 Programs are in a parallel Excel workbook, COFlag.xls, which we install and use in the same way as described in Chapter 1 - Using the CO^3 System. Like CO.xls, COFlag.xls has worksheets, or sheets.. Of these, the following are the same for both CO.xls and COFlag.xls:

- Construction Cost Sheet
- Impact Sheet

- Daily Cost Sheet

The COFlag.xls equivalents for the other three CO.xls worksheets are the following:

- CO.xls Traffic Sheet ⇒ COFlag.xls Flag Sheet
- CO.xls Input Sheet ⇒ COFlag.xls Flag Input Sheet
- CO.xls Route Sheet ⇒ COFlag.xls Flag Route Sheet

4.2 FLAGGING OPERATIONS

4.2.1 FLAGGING VARIABLES

4.2.1.1 Zone Travel Time

Vehicles can enter the flagged work zone only when the gate at their end is open, which also requires the entrance gate at the other end is closed. In this Sec. 4.2, we will use the term **travel *x*,** for short, to identify **zone method travel *x***, except where it might be unclear. For example, **travel time** = zone method travel time = time it takes each vehicle to travel through the zone during construction is calculated from

$$\text{travel time (min)} = \frac{[\text{travel distance (mi)}] * (60\ \text{min / hr})}{[\text{travel speed (mph)}]} \tag{63}$$

where **travel distance** (mi) = length of the flagged work zone = distance between flagging gates, **travel speed** (mph) = speed of vehicles in the flagged work zone.

4.2.1.2 Gate Operation

Fig. 4-2 shows gate cycling for a flagged work zone, with time moving from left to right, starting with the east gate closing, A. **Gate open** (min) = length of time a gate is open, **gate closed** (min) = length of time a gate is closed, and **dead time** (sec) = dead time = time between the last vehicle from one direction leaving the zone and the gate being opened for vehicles from the waiting direction to enter the zone (default = 15 sec). For example, in Fig. 4-2 the last east-bound vehicle that entered the zone before the west gate closed at D will exit the zone through the east gate at E = D + travel time, and the east gate will be opened at F = E + dead time for west-bound traffic to enter the zone.

Fig. 4-2 describes the following gate operations:

- West-bound (WB) traffic that has entered the east gate before it closes at A.
- Each WB vehicle takes travel time to traverse the zone, and the last WB vehicle exits the zone at B = A + travel time.
- West gate opens at C = B + dead time, east-bound (EB) traffic enters the zone during CD = gate open, the west gate closes at D, and future EB traffic must queue until the west gates opens at I to enter the zone.
- Each EB vehicle takes travel time to traverse the zone, and the last EB vehicle exits the zone at E = D + travel time.

- East gate opens at F = E + dead time, WB traffic that has been queuing since A enters the zone during FG = gate open, the east gate closes at G, and future WB traffic must queue until the east gate opens again to enter the zone. The east gate has been closed during AF.
- Each WB vehicle takes travel time to traverse the zone, and the last WB vehicle exits the zone at H = G + travel time.
- West gate opens at I = H + dead time, and EB traffic that has been queuing since D begins entering the zone. The west gate has been closed during DI.

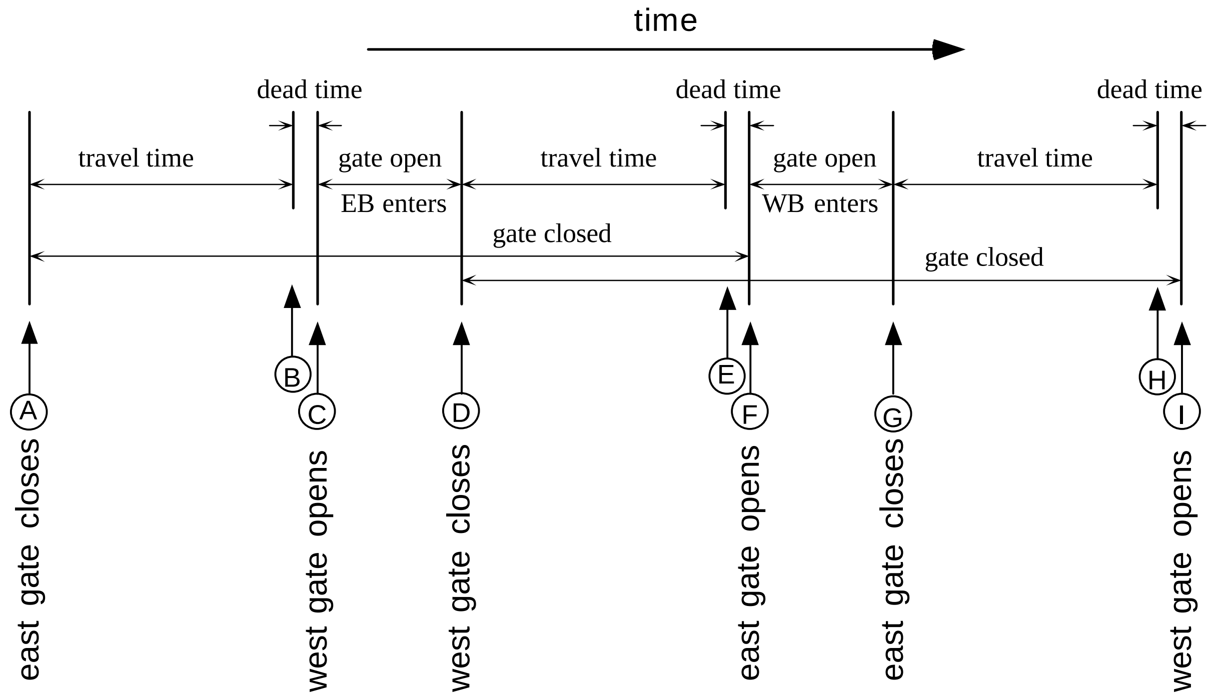

Fig. 4-2 Gate Operation versus Time

Gate open capacity (Vph) = capacity when gate is open = number of vehicles that enters the zone while a gate is open is dependent on **headway** (sec) = headway time per vehicle (default = 3 sec) = interval of time each vehicle requires, on average, to enter the zone when the gate is open,

$$\text{gate open capacity}(V/hr) = \frac{3600\ (sec/hr)}{\text{headway}\ (sec/V)} \quad (64)$$

With headway = default = 3 sec, gate open capacity = 3600 / 3 = 1200 Vph.

From Fig. 4-2, AG and CI are each complete gate cycles, from which we see that one gate cycle is (assuming all time units are the same):

$$\begin{aligned} \text{gate cycle} &= 2*(\text{gate open} + \text{travel time} + \text{dead time}) \\ &= \text{gate open} + \text{gate closed} \end{aligned} \quad (65)$$

and

$$\text{gate closed} = \text{gate open} + 2*(\text{travel time} + \text{dead time}) \quad (66)$$

Therefore, the length of time gates are closed is a function of the length of time gates are open, and the longer gates are open, the longer they are closed. And each time traffic is reversed in the zone, there is lost time = travel time + dead time.

4.2.1.3 Gate Delay and Capacity

Gate delay = time a vehicle waits for its gate to open. **Total delay** per vehicle is the sum of speed delay, gate delay, and backup delay. The maximum a vehicle can wait when capacity ≥ demand is maximum gate delay = gate closed. For example, a vehicle that arrives at a gate just as it closes will wait the entire gate closed time. The average gate delay is half the maximum gate delay, so for gate times = minutes, travel time = hours, and dead time = seconds:

$$\begin{aligned}\text{gate delay} &= 0.5*(\text{gate closed})\\ &= 0.5*(\text{gate open}) + (\text{travel time})*60 + \frac{(\text{dead time})}{60}\end{aligned} \qquad (67)$$

A gate is open twice [= 2 * (gate open)] per gate cycle, and the fraction of time that a gate is open is

$$\begin{aligned}\%\text{ open} &= \frac{2*(\text{gate open})}{\text{gate cycle}} = \frac{2*(\text{gate open})}{2*\left[\text{gate open} + (\text{travel time})*60 + \frac{(\text{dead time})}{60}\right]}\\ &= \frac{\text{gate open}}{\text{gate open} + (\text{travel time})*60 + \frac{(\text{dead time})}{60}}\end{aligned} \qquad (68)$$

Therefore, capacity in both directions is a function of length of time gates are open or closed,

$$\begin{aligned}\text{capacity} &= (\text{gate open capacity})*[\%\text{ open}]\\ &= \left[\frac{3600}{\text{headway}}\right]*\left[\frac{\text{gate open}}{\text{gate open} + (\text{travel time})*60 + \frac{(\text{dead time})}{60}}\right]\\ &= \left[\frac{3600}{\text{headway}}\right]*\left[1 - \frac{(\text{travel time})*60 + \frac{(\text{dead time})}{60}}{\text{gate open} - \left((\text{travel time})*60 + \frac{(\text{dead time})}{60}\right)}\right]\end{aligned} \qquad (69)$$

Thus, the longer the gates are open (and closed), the greater the capacity, but the greater the gate delay. The maximum theoretical capacity occurs when we hold one gate open all the time and keep the other gate closed all the time, in which case capacity = open gate capacity as described by Eq. (64), for which the default = 1200 Vph. However, this never happens (we hope), because it does not allow two-way travel in one lane.

4.2.1.4 Saturation

Saturation consists of opening and closing the gates so that capacity = demand. Vehicles arrive at a gate at an average arrival = (3600 sec / hr) / (demand Vph). When their entrance gate is closed, they queue at the average arrival. At saturation, we hold each gate open until all vehicles that have arrived have passed the gate, then the gate is closed, even if another vehicle will soon arrive. For example, if there are 30 vehicles in the west-bound queue when the east gate (the west-bound gate) is opened, and another 5 vehicles arrive in the queue before the entire queue has passed the gate, then all 35 are admitted. However, if we see another vehicle approaching but still 100 yd away, we still close the gate and the trailing vehicle starts the next queue. Therefore, as demand increases or decreases, gate times and gate delay increase and decrease.

We can calculate the time gate *i* is held open at saturation,

$$(\text{gate open})_{\text{sat}} = \frac{2 * \text{demand}_i * \text{headway} * \left((\text{travel time}) * 60 + \frac{(\text{dead time})}{60} \right)}{3600 - (\text{demand}_1 + \text{demand}_2) * \text{headway}} \tag{70}$$

but we operate the gates to fit the actual vehicle arrivals, not by applying Eq. (70). The number of vehicles in the platoon is the number that arrive during a

Vehicles travel through the zone in a **platoon** = vehicles that arrive during a gate cycle.

$$\text{platoon}_i = \text{demand}_i * (\text{gate open} + \text{gate closed}) \tag{71}$$

The platoon at saturation can be calculated indirectly from the number of vehicles that can pass through the gate while it is open,

$$\text{platoon}_{\text{sat}\cdot i} = \frac{(\text{gate open})_{\text{sat}\cdot i}}{\text{headway}} \tag{72}$$

At saturation, gate delay is calculated from:

$$\text{gate delay.} = \left((\text{travel time}) * 60 + \frac{(\text{dead time})}{60} \right) * \left[1 + \frac{2 * \text{demand}_1 * \text{demand}_2 * \text{headway}}{(\text{demand}_1 + \text{demand}_2) * [3600 - (\text{demand}_1 + \text{demand}_2) * \text{headway}]} \right] \tag{73}$$

where demand_1 = demand in one direction, and demand_2 = demand in the other direction.

4.2.1.5 Backups and Maximum Gate Times and Capacity

A backup occurs when traffic in one or both directions exceeds capacity, because more vehicles arrive at a gate than can enter the zone during the time the gate is open. A good policy is to operate gates to match actual demand in both directions, holding gates open longer when demand is heavy. This minimizes traffic waiting time. The queues that form at each gate soon after they close are not backups, they are a normal part flagging, even when traffic is light. The wait time of the vehicles is their gate delay. We normally hold a gate open until all vehicles that have arrived enter the zone, making up the platoon. However, when demand exceeds capacity that can be accommodated by adjusting gate time, backups occur at the rate by which demand exceeds capacity. For example, if demand_{west} = 700 VPH, and $\text{demand}_{\text{east}}$ = 500 VPH, then total demand =

700 + 500 = 1200 VPH, which will exceed capacity by an amount that depends on how long we allow the gates to be closed.

Formally, a vehicle is backed up by a gate when the vehicle cannot enter the gate before the gate is next closed. If a car arrives at a gate and there are 20 vehicles ahead of it and 20 or fewer will be allowed to enter the gate before it next closes, the car is backed up. If 21 or more vehicles will be allowed to enter the gate, the car is just waiting for its turn in the normal cycle of the gate; it is not backed up. The backup ahead of a vehicle = the number of vehicles ahead of it that are backed up. That is, if 20 vehicles are ahead of a car, and only 12 can enter the gate before it is next closed, backup = 20 – 12 = 8 vehicles.

We must select and input to COFlag a maximum average time we will allow the two gates to be closed = [(gate closed)$_{all}$ (min)] = average allowable gate closed time. Then from Eq. (66), the average time gates will be kept open is

$$(\text{gate open})_{\text{all}} = (\text{gate closed})_{\text{all}} - 2*\left((\text{travel time})*60 + \frac{(\text{dead time})}{60}\right) \tag{74}$$

and the total time lanes are open per cycle = 2*(gate open)$_{all}$. This limits capacity to a maximum of capacity$_{max}$ (Vph) = maximum capacity of flagging zone in both directions,

$$\begin{aligned}\text{capacity}_{\text{max}} &= \left[\frac{3600}{\text{headway}}\right]*\left[1-\frac{(\text{travel time})*60+\frac{(\text{dead time})}{60}}{(\text{gate closed})_{\text{all}}-\left((\text{travel time})*60+\frac{(\text{dead time})}{60}\right)}\right] \\ &= \left[\frac{3600}{\text{headway}}\right]*\left[1-\frac{\frac{\text{travel distance}}{\text{travel speed}}*60+\frac{(\text{dead time})}{60}}{(\text{gate closed})_{\text{all}}-\left(\frac{\text{travel distance}}{\text{travel speed}}*60+\frac{(\text{dead time})}{60}\right)}\right]\end{aligned} \tag{75}$$

We generally adjust the maximum length of time each gate is opened to its relative demand. Therefore, when total demand = demand$_1$ + demand$_2$ > capacity, we keep each gate *i* open

$$\begin{aligned}(\text{gate open})_{\text{all}\cdot i} &= \left(\frac{2*\text{demand}_i}{\sum_i \text{demand}_i}\right)*(\text{gate open})_{\text{all}} \\ &= \left(\frac{2*\text{demand}_i}{\sum_i \text{demand}_i}\right)*\left[(\text{gate closed})_{\text{all}}-2*\left((\text{travel time})*60+\frac{(\text{dead time})}{60}\right)\right]\end{aligned} \tag{76}$$

This creates backup in each direction equal to its relative demand, and each direction has the same delays.

4.3 USING CO³FLAG COMPUTER PROGRAMS

4.3.1 FLAG INPUT SHEET (FLAG INPUT TAB)

4.3.1.1 General

The Flag Input Sheet is the same as the Input Sheet, except for the variables that are unique to the COFlag model. An example is shown in Fig. 4-1. Each of the pertinent parts of the Input Sheet will be described below, accompanied by the pertinent portion of Fig. 4-1, in which the unique variables are shown **bold**. Only the unique variables will be described here. The difference is primarily due to the flagged work zone having only one lane open in which incoming traffic from both directions must alternate. Therefore, when vehicles travel through the zone in one direction, vehicles traveling in the opposite direction must wait outside the zone until every vehicle coming toward them has traveled through the zone. Therefore, travel in each direction is at the expense of travel in the other direction. This is fundamentally different from normal two-way travel, in which travel in one direction is considered independent of travel in the other.

When demand is low, flagging directions are reversed often, to minimize waiting at the gates. When demand is higher, flagging directions are reversed less often, because each reversal takes its own time. Under all but the lightest demand, vehicles queue at their entrance gate to the zone and then travel through the zone in a convoy or platoon. Therefore, travel is assumed to be at the speed under heavy traffic, akin to speed (with D=C) in CO^3 normal two-way travel.

In addition, the impact of flagging compared two-way travel is much more extreme than the impact of closing all but one lane of two or even three lanes of one-way traffic. For example, in normal two-way travel is typically 1200 Vph in each direction = 2400 Vph in both directions. In contrast, the maximum capacity of one lane of alternating traffic is in the order of magnitude of 600 Vph, which is half the capacity of one-way traffic in one lane. Therefore, in the COFlag Traffic Sheet, we explicitly identify the periods in which there is flagging instead of normal two-way travel. COFlag has speed delay and decreases in design demand, but our explicit identification of flagging periods eliminates the need for threshold and range values.

4.3.1.2 Capacity Input

CAPACITY INPUT		
(1) **total capacity both ways (V/hr)**		

- **normal total capacity both ways** (V/hr) = number of vehicles per hour that can be carried by both lanes under normal conditions = the sum of the capacity of each lane (default = 2400 V/hr = 2 * 1200 V/hr/lane). This is the capacity at which any backups during flagging will dissipate after flagging ends. We input capacity here, to document its estimation.

4.3.1.3 Distance, Speed, and Flag Operation Input

DISTANCE AND SPEED INPUT		distance	speed
1	**work zone method travel**	1.0	**25**
1	work zone normal travel	1.0	60
1	diversion method travel	10.0	45
1	diversion normal travel	6.0	60
FLAG OPERATION INPUT			
2	**vehicle headway at gate (sec)**	**3**	
2	**dead time at gate when direction changes (sec)**	**15**	
3	**allowable gate closed time (min.)**	**8**	

The input variables are the same as in the Input Sheet except for the following:

- COFlag does not have speed delay input. Speed in a flagged work zone is generally not a function of capacity for speed delay, because vehicles travel through the flagged work zones in platoons with minimum headway, in the same manner as vehicles in normal work zones where demand = capacity.
- **work zone method travel distance** = **zone method distance** = **travel distance** (mi) is length of the flagged work zone = our estimate of the distance between the flagging gates (see Sec. 4.2.1.1).
- **work zone method travel speed** = **zone method speed** = **travel speed** (mph) is our estimate of the average speed of vehicles traveling the zone method distance (see Sec. 4.2.1.1). The work zone method speed is normally the equivalent to speed (when D=C) in the Input Sheet.
- **vehicle headway at gate = headway** (sec) headway time per vehicle (default = 3 sec) = our estimate of time interval between vehicles entering the zone when the gate is open (see Sec. 4.2.1.2, pg. 4-2).
- **dead time** at gate when direction changes = **dead time** (sec) = time between the last vehicle from one direction leaving the zone and the gate being opened for vehicles from the waiting direction to enter the zone (default = 15 sec) (see Sec. Sec. 4.2.1.2, pg. 4-2). The default value accounts for normal change over from one direction to the other, for the flagger to verify there are no stragglers still in the work zone and to get traffic moving in the opposite direction. Dead time will be much larger if the contractor delays opening the gates to perform work when the zone is clear of traffic.
- **allowable gate closed time** = **(lane closed)$_{\mathbf{all}}$** (min) = average allowable gate closed time = (lane closed)$_{all}$ (see Sec. 4.2.1.5, pg. 4-5). This establishes maximum capacity of flagging zone, above which demand will backup. Normally, we select allowable gate closed time to be about three or four times the minimum gate delay. We selected a factor of three, to calculate allowable gate closed time ≈ 3 * 2.65 ≈ 8 min in this example, that is in scale with diversion delay = 7.33 min (see Sec. 4.3.1.4)

4.3.1.4 Calculation of Vehicle Travel and User Cost

WORK ZONE TRAVEL		
method travel time (min)	2.40	
normal travel time (min)	1.00	
speed delay (min)	1.40	
gate delay at D~0 (min)	**2.65**	
gate delay at maximum capacity (min)	**4.00**	
gate and speed delay at D~0 (min)	**4.05**	
gate+speed delay at max capacity (min)	**5.40**	
maximum capacity (V/hr)	**606**	
ZONE USER COST	**cars**	**trucks**
gate+speed delay user cost at D~0	**$0.73**	**$0.73**
gate+speed delay user cost at max capacity	**$0.97**	**$0.97**
DIVERSION TRAVEL		
method travel time (min)	13.33	
normal travel time (min)	6.00	
diversion delay (min)	7.33	
extra diversion travel distance (mi)	4.0	
DIVERSION USER COST	cars	trucks
diversion delay user cost	$1.32	$1.32
diversion distance user cost	$1.20	$4.00
diversion user cost	$2.52	$5.32
backup delay balance (min)	8.61	24.18

- **zone method travel time**, **zone normal travel time**, and **speed delay** are calculated as described for the Input Sheet in Eq. (4) and (5) in Sec. 1.5.1.7, pg. 1-14.
- **gate delay at D~0** (min) = average gate delay per vehicle when demand is very light and gate open → 0. Actual gate delay (min.) when demand is very light and gate open → 0 will vary between 0 and (gate closed)$_{min}$.

  minimum average gate delay = 0.5 * (gate closed)$_{min}$ (77)

  where in accord with Eq. (67) when gate open → 0,

  (gate closed)$_{min}$ = (zone method travel time) * 60 + (dead time) / 60 (78)

- **gate delay at maximum capacity** (min) = average gate delay per vehicle when two-way demand ≥ capacity and gate open = (gate open)$_{all}$ and gate closed = (gate closed)$_{all}$. Actual gate delay (min.) when two-way demand ≥ capacity and gate open = (gate open)$_{all}$ and gate closed = (gate closed)$_{al}$ will vary between 0 and (gate closed)$_{all}$. By Eq. (67),

  gate delay at maximum capacity = 0.5 (gate closed)$_{all}$ (79)

- **gate and speed delay at D~0** (min) = (gate delay at D~0) + (speed delay) (80)
- **gate and speed delay at maximum capacity (min)** = (gate delay at maximum capacity) + (speed delay) (81)
- **maximum capacity (Vph)** = capacity$_{max}$ as calculated by Eq. (75).

PROJECT INPUT AND DOCUMENTATION		Project:	M-43 Overlay, Zimmer to Cornell
FLAGGING OPERATION		By:	
Copy This Sheet		Other:	
METHOD INPUT	Standard		
method title	Flagging		
VEHICLE INPUT	cars	trucks	
(1) design demand (%)	98.0%	2.0%	Est.
(0) user cost per hour ($/V hr)	$10.79	$10.79	default
(0) user cost per mile, ($/V mi)	$0.30	$1.00	default
(4) user cost per cancellation, ($/V)	$1.20		Cars: about 1/2 diversion cost. Trucks: disregard, too few to consider.
ROUTE TITLES	Standard		
DISTANCE AND SPEED INPUT	distance	speed	
(1) work zone method travel	1.0	25	1 mi zone @ 25 mph ext.
(1) work zone normal travel	1.0	60	Zone = 1 mi at at a time. Normal speed = 60 mph.
(1) diversion method travel	10.0	45	Zimmer - Linn - N Meridian - W Jolly - Okemos = 12 mi on map. 45 mph est.
(1) diversion normal travel	6.0	60	Normal between Zimmer to Okemos ~ 6 mi @ 60 mph.
FLAG OPERATION INPUT			
(2) vehicle headway at gate (sec)	3		default
(2) dead time at gate when direction changes (sec)	15		default
(3) allowable gate closed time (min.)	8		Use ~ 3 * minimum gate delay = 3 * 2.65 ~ 8 min.
WORK ZONE TRAVEL			General Comments:
method travel time (min)	2.40		
normal travel time (min)	1.00		
speed delay (min)	1.40		
gate delay at D~0 (min)	2.65		
gate delay at maximum capacity (min)	4.00		
gate and speed delay at D~0 (min)	4.05		
gate+speed delay at max capacity (min)	5.40		
maximum capacity (V/hr)	606		
ZONE USER COST	cars	trucks	
gate+speed delay user cost at D~0	$0.73	$0.73	
gate+speed delay user cost at max capacity	$0.97	$0.97	
DIVERSION TRAVEL			
method travel time (min)	13.33		
normal travel time (min)	6.00		
diversion delay (min)	7.33		
extra diversion travel distance (mi)	4.0		
DIVERSION USER COST	cars	trucks	
diversion delay user cost	$1.32	$1.32	
diversion distance user cost	$1.20	$4.00	
diversion user cost	$2.52	$5.32	
backup delay balance (min)	8.61	24.18	
DECREASE TO DEMAND INPUT			
(6) canceled cars (with no delay) (%)			Most people will know hours of work, and there are always delays during work.
(6) canceled trucks (with no delay) (%)			Disregard: There are very few trucks.
(6) canceled cars (with delay) (%/min)	1.5%		Average trip = 10 mi = 10 min. Added delay ~ 4 w/ light traffic, diversion delay = 7 min. Est 12% cancel @ (delay=8 min) = 12% / 8 min = 1.5%.
(6) canceled trucks (with delay) (%/min)			Disregard: There are very few trucks.
(5) diverted cars (with no delay) (%)			Most people will know hours of work, and there are always delays during work.
(5) diverted trucks (with no delay) (%)			Disregard: There are very few trucks.
(5) diverted cars (with delay) (%/min)	2.0%		Diversion is complex. ~ 20% divert @ (backup delay balance ~ 9 min) and 50% @ 20 min delay: Use 2%/min.
(5) diverted trucks (with delay) (%/min)			Disregard: There are very few trucks.
OTHER USER COST INPUT	cars	trucks	
other user cost per vehicle ($/V)	$0.00	$0.00	default
user cost per diversion ($/V)	$2.52	$5.32	
CAPACITY INPUT	normal		
(1) total capacity both ways (V/hr)	2400		default

Fig. 4-3 Flag Input Sheet

- **gate and speed delay user cost at D~0** and **gate and speed delay user cost at maximum capacity** ($/V), in parallel with Eq. (11) in Sec. 1.5.1.7, pg. 1-14 for speed delay, is calculated from

  gate and speed delay user cost ($/V) = [gate and speed delay (hr)] * [user cost per hour ($/V-hr)] + [extra work zone travel distance (mi)] * [user cost per mile ($/mi)] (82)

- **diversion travel** and **diversion user cost** are calculated as described for the Input Sheet in Sec. 1.5.1.7, pg. 1-14.
- **backup delay balance** (min) in parallel with Eq. (15) in Sec. 1.5.1.7, pg. 1-14 for the Input Sheet, is calculated from

$$\text{backup delay balance (min)} = \frac{[\text{diversion user cost (\$)}] - [\text{gate} + \text{speed delay user cost at max capacity (\$)}]}{[\text{user cost per hour(\$ / hr)}] / [60 \text{ (min / hr)}]} \qquad (83)$$

4.3.2 FLAG ROUTES SHEET (FLAG ROUTES TAB)

The Flag Routes Sheet is the same as the Routes Sheet, except for the variables that are unique to the COFlag model. This parallels the relationship between the Flag Input Sheet and the Input Sheet. The only differences between the Flag Routes Sheet and the Routes Sheet are the variables in the Flag Input Sheet that are described in Sec. 4.3 on the Flag Input Sheet. Like the Routes Sheet, the Flag Routes Sheet is not needed for projects that do not have complex routes.

Fig. 4-4 shows an example of a simple routing that is the equivalent of the Second Street routing in the example in Fig. 1-4, pg. 1-18 in Sec. 1.5.2.1**.** Though the routing is simple, the diversion route consists of three streets that have different speeds, which warrants using the Flag Routes Sheet. Its application to Second St. - Diversion Travel supports comparing the Flag Routes Sheet with the Routes Sheet.

Fig. 4-5 is the Flag Routes Sheet for the routing in Fig. 4-4. The Route Distance, Speed, and Time table, also called the Route Travel table, is the same as the Second St. routing in Fig. 1-5, pg. 1-20. The Route User Costs table has the same values as the Second St. - Diversion Travel route in **Fig. 1-5**. However, the Route User Costs table in Fig. 4-5 has arranged differently to demonstrate the dependencies of calculated travel and user cost variables on input variables. Therefore, each of the four double columns has a different set of input variables input:

(1) **work zone input and output** has input only for work zone input, and it shows the output values that are completely defined by work zone input.

(2) **diversion input and output** has input only for diversion input, and it shows the output values that are completely defined by diversion input.

(3) **headway/dead time input and output** includes all input variables except allowable gate closed time = blank, and it shows the output values that do not depend on allowable gate closed time.

(4) **ALL input and output** has all input variables, and it shows the complete set of output values for Second St. - Diversion Travel.

Of course, we note the same differences in variables between the Flag Routes Sheet and Routes Sheet that we saw between the Flag Input Sheet and Input Sheet. In particular, the Flag Routes Sheet lacks threshold and range values, and it includes flag operation variables. In particular, distance and speed input are the same, with Flag Routes zone method travel speed = 25 mph = Routes zone method travel speed (when D=C). Flag Routes speed delay = 1.96 min = Routes speed delay (when D=C). However, Flag Routes has gate delay that varies between 3.85 and 5.00 min, which Routes does not have. Therefore, Flag Routes gate and speed delay user cost varies between $1.05 and $1.25, which is much larger than Routes speed delay user cost (when D=C) = $0.35. Flag Routes and Routes have the same diversion travel and user cost values. The differences in zone delays produce Flag Routes backup delay balance = 1.50 min for cars and 9.29 min for trucks, whereas Routes backup delay balance = 6.50 min for cars and 14.29 min for trucks. Maximum capacity = 478 Vph for the flagging operation in Flag Routes, for allowable gate closed time = 10.

4.3.3 FLAG SHEET (FLAG TAB)

4.3.3.1 General

The Flag Sheet is the COFlag equivalent to the Traffic Sheet, and it is our connection to the COFlag Program that computes period and daily values of traffic congestion and user cost due to construction using flagging operations. The Flag Sheet shares about half its variables with the Traffic Sheet, but it has several major differences:

1. Each COFlag computer run computes and reports values for both directions of travel for the flagging operation, because both directions are completely interdependent in a flagging operation. Therefore, Flag Sheet demand and capacity are demand and capacity of the entire flagging operation, which is the combination or sum of the demand and capacity of the two lanes from two directions that share flagging.
2. Flagging variables are key inputs and outputs of the Flag Sheet.. Actual operating conditions are dependent on flagging zone operating variables and on demand.
3. Capacity of flagging operations is determined by their operating variables, and capacity is not an input variable.
4. Beginning and ending of daily flagging operations is explicit input to the Flag Sheet. In combination with item 3, this eliminates threshold and range capacities that implicitly identify lane closures in the Traffic Sheet.

The Flag Sheet contains the same five views as the Traffic Sheet:

- The **Summary View** is the input form for the COFlag Program, its buttons drive the COFlag Program, and it summarizes COFlag Program results for a combination of both directions of travel for up to four methods. (see)
- The **Overall View** shows input and provides detailed output of COFlag Program results for all variables for the latest COFlag run. Therefore, it shows detailed information for the combination of both directions of travel using one traffic maintenance method. It shows all information in all the views for the latest COFlag run.
- The **Traffic View** parallels the Overall View for the latest COFlag run. It shows input and provides a traffic subset of COFlag Program results for a flagging operation using one method.

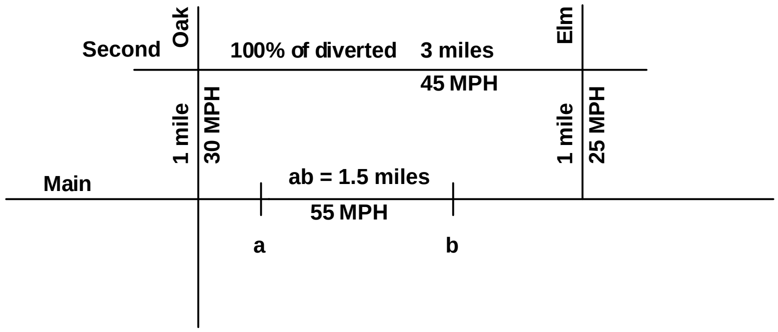

Fig. 4-4 Map of Example Routes

FLAG ROUTE CALCULATIONS

Project: M-43 Overlay, Zimmer to Cornell
By:
Other:

ROUTE USER COSTS — Copy This Sheet

VEHICLE USER COST INPUT	cars	trucks
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00

ROUTE INPUT	Standard							
DISTANCE AND SPEED INPUT (mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone method travel	1.0	25	1.0	25	1.0	25		
normal travel	1.0	60	1.0	60	1.0	60		
diversion method travel	10.0	45	10.6	45	9.3	45		
normal travel	6.0	60	5.6	60	5.0	60		
FLAG OPERATION INPUT								
vehicle headway at gate (sec)	3		3		3			
dead time at gate when direction changes (sec)	15		15		15			
allowable gate closed time (min.)	8		8		8			
WORK ZONE TRAVEL								
method travel time (min)	2.40		2.40		2.40			
normal travel time (min)	1.00		1.00		1.00			
speed delay (min)	1.40		1.40		1.40			
gate delay at D~0 (min)	2.65		2.65		2.65			
gate delay at maximum capacity (min)	4.00		4.00		4.00			
gate and speed delay at D~0 (min)	4.05		4.05		4.05			
gate and speed delay at maximum capacity (min)	5.40		5.40		5.40			
maximum capacity (V/hr)	606		606		606			
ZONE USER COST	cars	trucks	cars	trucks	cars	trucks	cars	trucks
gate and speed delay user cost at D~0	$0.73	$0.73	$0.73	$0.73	$0.73	$0.73		
gate and speed delay user cost at maximum capacity	$0.97	$0.97	$0.97	$0.97	$0.97	$0.97		
DIVERSION TRAVEL								
diversion method travel time (min)	13.33		14.13		12.40			
diversion normal travel time (min)	6.00		5.60		5.00			
diversion delay (min)	7.33		8.53		7.40			
extra diversion travel distance (mi)	4.0		5.0		4.3			
DIVERSION USER COST	cars	trucks	cars	trucks	cars	trucks	cars	trucks
diversion delay user cost	$1.32	$1.32	$1.53	$1.53	$1.33	$1.33		
diversion distance user cost	$1.20	$4.00	$1.50	$5.00	$1.29	$4.30		
diversion user cost	$2.52	$5.32	$3.03	$6.53	$2.62	$5.63		
backup delay balance (min)	8.61	24.18	11.47	30.94	9.17	25.91		

Fig. 4-5 Flag Routes Sheet

- The **User Cost View** is like the Traffic View, except it reports a user cost subset of results.
- The **Combination View** or Combo View is like the Traffic View and User Cost view, except it reports a subset of their results.

4.3.3.2 Summary View

4.3.3.2.1 General

As stated above, the Summary View is the core of COFlag. Not only is it the place that we input and calculate traffic impact and user cost, but it is the primary report on which we document input and output and from which we make decisions. The Summary View consists of the following elements, of which those that differ from the Summary View of the Traffic Sheet are printed **bold**:

- Input
  - For the project as a whole
    - Title block
    - Period length and traffic growth
    - Vehicle input
    - Period input: historical demand for each period in each direction
  - For each traffic direction and maintenance method
    - Method input
    - **Distance and speed**
    - **Flag Operations**
    - Decrease to demand
    - Other user cost
    - **Period input:**
      - **Backup at start of flagging**
      - **Flagging periods**
      - **Capacity at end of flagging**
- Control buttons
  - Navigation buttons, which take us to various locations in views
  - Action buttons, which direct COFlag to perform specific calculations or to print reports.
- Output values
  - **Design demand for both directions**
  - **Actual demand for both directions**
  - **Summary output of traffic impact and user cost**

We generally use the Summary View in this same sequence. We input project information, we input method information, we calculate traffic delay and user cost values for each method, we move from one view to another to review results, and we print Summary View and/or other view(s) to document input and report results.

Here, as in other sheets, input cells (and often main headings for input) are indicated by a pale yellow background on the computer model and light gray background in this User's Manual and in black and white output. Delays and user cost are calculated from input cells (cells with pale yellow background) found in the Summary View. Input cells may have one of three types of values: numerical, text, or "blank." The numerical values provide the basis of all calculations and are limited to non-negative, decimal numbers. The text values (e.g., "SE", "7A", and "7A-5P") provide descriptive information only (e.g., a description of a method). Thus, they have no effect on the outcomes of calculations. An input cell left empty does not necessarily imply a value of zero in certain calculations.[9] Therefore, the user should input zero when input is known to be zero, and leaving a cell blank when a zero should have been input can produce incorrect results. Input cells require values by keyboard entry in the case of numerical and text values, or by acceptance of a default value.

The input data from the Flag Input Sheet, which were shown in shaded cells, are also input to the Summary View, either as project input or for one or more methods. Most values calculated in the Flag Input Sheet are not shown in the Summary View. This is part of what makes the Flag Input Sheet useful, because it provides information that would not otherwise be known.

Data are entered into the Summary View in three ways: (1) retaining default or other values already entered, (2) directly entering values, and (3) copying and pasting values from other cells. Of most concern is that the integrity of the CO^3 runs not be disturbed. Therefore, we never input anything except to the cells shown as input cells by their color. We also do not generally want to disturb formatting in cells. Also it is best to paste only the values of the data from other cells, not the cells' formatting or formulas. Therefore, when we paste, we Paste Values, which is a special way of pasting. This can be done in any of three ways. First, we go to the cell in which we want to Paste Value. Then to Paste Value: we (1) select the cell(s) in which to Paste Value the desired data by clicking on the upper left cell, and (2) either (a) click the Paste Value icon on the toolbar or (b) click the Paste Values icon **Paste Values** on the worksheet (where available) or (c) click on Edit on the toolbar, click Paste Special on its foldout menu, click Values and then OK on the Paste Special window.

The sections below will describe each component of the COFlag Flag Sheet Summary View that differs from the CO^3 Traffic Sheet Summary View. We go to Sec. 1.5.3.2, pg. 1-22 for descriptions of the sections that do not differ from the Traffic Sheet Summary View. For clarity, a figure representing the section of the Summary View being discussed is located at the top of each section.

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[9] In some instances, the spreadsheet may show a "blank" for some values, when the correct value is 0. This happens particularly for *speed delay* = 0 and *speed delay user cost* = 0, when *work zone normal travel speed* = *threshold speed* (*when D » 0*). The "blank" in place of zero occurs when the spreadsheet is configured to show zero as "blank." To change this, with your mouse click on "Tools" in the toolbar at the top of the spreadsheet. In the "Tools" menu that results, click "Options." In the "Options" window that results, click "View." In the "View" window that results, click "Zero values" such that it shows a check mark (✓) to its left. Then click on "OK." This will make the spreadsheet show zero, rather than showing zero as "blank."

4.3.3.2.2 Distance and Speed Input

METHOD INPUT		METHOD 1		METHOD 2		METHOD 3		METHOD 4	
	method title	F, 7A-5P		F, 5A-3P		F, 9A-3P		F, 8P-6A Night	
DISTANCE AND SPEED INPUTS	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	1.0	25	1.0	25	1.0	25	1.0	25
	normal travel	1.0	60	1.0	60	1.0	60	1.0	60
diversion	method travel	10.0	45	10.0	45	10.0	45	10.0	45
	normal travel	6.0	60	6.0	60	6.0	60	6.0	60
FLAG OPERATION INPUTS									
	vehicle headway at gate (sec)	3		3		3		3	
	dead time at gate when direction changes (sec)	15		15		15		15	
	allowable gate closed time (min.)	8		8		8		8	
DECREASE TO DEMAND									
	canceled cars (with no delay) (%)								
	canceled trucks (with no delay) (%)								
	canceled cars (with delay) (%/min)	1.5%		1.5%		1.5%		1.5%	
	canceled trucks (with delay) (%/min)								
	diverted cars (with no delay) (%)								
	diverted trucks (with no delay) (%)								
	diverted cars (with delay) (%/min)	2.0%		2.0%		2.0%		2.0%	
	diverted trucks (with delay) (%/min)								

These input data are required for each traffic maintenance method we model (for example, do flagging from 7:00 am to 5:00 pm). The data that are unique to flagging are shown above in a larger font, and they are explained for the Flag Input Sheet, in Sec. 4.3.1.3:

- **work zone method travel speed** = **zone method speed** = **travel speed** (mph)
- **vehicle headway at gate = headway** (sec) headway time per vehicle (default = 3 sec)
- **dead time** at gate when direction changes = **dead time** (sec)
- **allowable gate closed time** = **(lane closed)$_{\mathbf{all}}$** (min) = average allowable gate closed time = (lane closed)$_{all}$

The data that are common to the Summary View of the Traffic Sheet are explained in Chapter **1, Sec. 1.5.1.4 and 1.5.1.5**.

Each input is for a particular construction method. Inputs are for both directions of travel. As previously mentioned, each Traffic Sheet can analyze up to four different traffic maintenance methods. We can directly copy the values from an appropriate Input Sheet, using Copy and either clicking the Paste Values icon  on the Excel toolbar or clicking the Paste Values Paste Values button on the Summary View.

SummaryView - Flagging Operation

Copy This Sheet	period length (min)	60		
	annual traffic growth (%)	3.00%		
Update	years of growth	2		
VEHICLE INPUT		cars	trucks	
	design demand (%)	98.0%	2.0%	
	user cost per hour ($/V hr)	$10.79	$10.79	
	user cost per mile, ($/V mi)	$0.30	$1.00	
	user cost per cancellation, ($/V)	$1.20		

PROJECT INFORMATION			REPORT INFORMATION	
PROJECT TITLE	M-43 Overlay Zimmer to Cornell		REPORT TITLE	DETAILED USER COST REPORT SUMMARY VIEW
Paste Values	C.S.	33082	DIVISION	
	JOB #	36569A	REPORT BY	
	START DATE	April, 1995	REPORT DATE	4/1/94
NOTES:				

METHOD INPUT		METHOD 1		METHOD 2		METHOD 3		METHOD 4	
	method title	F, 7A-5P		F, 5A-3P		F, 9A-3P		F, 8P-6A Night	
DISTANCE AND SPEED INPUTS	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	1.0	25	1.0	25	1.0	25	1.0	25
	normal travel	1.0	60	1.0	60	1.0	60	1.0	60
diversion	method travel	10.0	45	10.0	45	10.0	45	10.0	45
	normal travel	6.0	60	6.0	60	6.0	60	6.0	60
FLAG OPERATION INPUTS									
	vehicle headway at gate (sec)	3		3		3		3	
	dead time at gate when direction changes (sec)	15		15		15		15	
	allowable gate closed time (min.)	8		8		8		8	
DECREASE TO DEMAND									
	canceled cars (with no delay) (%)								
	canceled trucks (with no delay) (%)								
	canceled cars (with delay) (%/min)	1.5%		1.5%		1.5%		1.5%	
	canceled trucks (with delay) (%/min)								
	diverted cars (with no delay) (%)								
	diverted trucks (with no delay) (%)								
	diverted cars (with delay) (%/min)	2.0%		2.0%		2.0%		2.0%	
	diverted trucks (with delay) (%/min)								
OTHER USER COST INPUT	Update	cars	trucks	cars	trucks	cars	trucks	cars	trucks
	other user cost per actual demand ($/V)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	user cost per diversion ($/V)	$2.52	$5.32	$2.52	$5.32	$2.52	$5.32	$2.52	$5.32
	Paste Values	Calculate		Calculate		Calculate		Calculate	

Summary | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

PERIOD VALUES (V/period)					(Backup at Start of Flagging) Flag Periods (Capacity at End of Flagging)						Demand	
direction:	E	W	Both Directions		(Bsof) Flag	demand	(Bsof) Flag	demand	(Bsof) Flag	demand	(Bsof) Flag	demand
period	historical			design	(Ceof)	actual	(Ceof)	actual	(Ceof)	actual	(Ceof)	actual
12 A	34	22	56	59							Flag	51
1 A	15	14	29	31							Flag	26
2 A	17	12	29	31							Flag	26
3 A	19	8	27	29							Flag	25
4 A	15	27	42	45			0				Flag	38
5 A	32	91	123	130			Flag	112			Flag	112
6 A	90	265	355	377			Flag	318				
7 A	227	659	886	940	Flag	667	Flag	667				
8 A	234	528	762	808	Flag	556	Flag	556				
9 A	220	455	675	716	Flag	579	Flag	579	Flag	586		
10 A	267	393	660	700	Flag	574	Flag	574	Flag	574		
11 A	377	403	780	828	Flag	634	Flag	634	Flag	634		
12 P	436	397	833	884	Flag	617	Flag	617	Flag	617		
1 P	442	431	873	926	Flag	615	Flag	615	Flag	615		
2 P	481	373	854	906	Flag	598	Flag	607	Flag	607		
3 P	550	463	1013	1075	Flag	645	2400					
4 P	664	479	1143	1213	Flag	647						
5 P	749	573	1322	1403	2400							
6 P	534	569	1103	1170								
7 P	395	421	816	866								
8 P	339	179	518	550							Flag	458
9 P	277	156	433	459							Flag	386
10 P	165	81	246	261							Flag	222
11 P	87	42	129	137							Flag	117
Total	6666	7041	13707	14542		6133		5279		3633		1461

SUMMARY OUTPUT	traffic method	F, 7A-5P Flagging	F, 5A-3P Flagging	F, 9A-3P Flagging	F, 8P-6A Night Flagging
	total user cost	$15,478	$11,061	$7,582	$1,722
	user cost of delays	$9,886	$7,279	$4,990	$1,194
	user cost of decreases	$5,592	$3,782	$2,593	$528
	maximum backup (V)	123	62	51	0
	maximum backup length (lane mi)	0.7	0.4	0.3	0.0
You can copy these values into Impact Sheet.	maximum delay (min.)	16.7	10.9	10.2	8.3
	average delay, except diversions (min)	1.1	7.7	7.6	4.5
	total delay, except diversions (V hr)	916	675	462	111
	total vehicles canceled(V)	1227	830	569	116
	total vehicles diverted (V)	1636	1106	758	154
	total decrease in demand (V)	2863	1936	1327	270
	% decrease in demand	32%	27%	27%	16%
	delay per diverted vehicle (min)	7.3	7.3	7.3	7.3
	total diversion delay (V hr)	200	135	93	19
	average delay, including diversions (min)	1.0	7.6	7.6	4.8
	total delay, including diversions (V hr)	1116	810	555	130
	user cost / design demand	$1.06	$0.76	$0.52	$0.12
	delay cost / actual demand	$1.61	$1.38	$1.37	$0.82
	work zone method travel time (min.)	2.4	2.4	2.4	2.4
	speed delay (min.)	1.4	1.4	1.4	1.4
	maximum capacity (V/hr)	606	606	606	606
	gate delay at maximum capacity (min.)	4.0	4.0	4.0	4.0
	maximum gate and speed delay (min.)	9.4	9.4	9.4	8.3
	maximum backup delay (min.)	7.3	1.5	0.8	0.0
Auto ON, Print ON, Now OK	validity of output	VALID	VALID	VALID	VALID

Fig. 4-6 Flag Sheet Summary View

4.3.3.2.3 Period Values

METHOD INPUT	METHOD 1	METHOD 2	METHOD 3	METHOD 4
method title	F, 7A-5P	F, 5A-3P	F, 9A-3P	F, 8P-6A Night

==

PERIOD VALUES (V/period)			(Backup at Start of Flagging) Flag Periods (Capacity at End of Flagging)								Demand	
direction:	E	W	Both Directions		(Bsof) Flag	demand	(Bsof) Flag	demand	(Bsof) Flag	demand	(Bsof) Flag	demand
period	historical			design	(Ceof)	actual	(Ceof)	actual	(Ceof)	actual	(Ceof)	actual
12 A	34	22	56	59							Flag	51
1 A	15	14	29	31							Flag	26
2 A	17	12	29	31							Flag	26
3 A	19	8	27	29							Flag	25
4 A	15	27	42	45			0				Flag	38
5 A	32	91	123	130			Flag	112			Flag	112
6 A	90	265	355	377			Flag	318				
7 A	227	659	886	940	Flag	667	Flag	667				
8 A	234	528	762	808	Flag	556	Flag	556				
9 A	220	455	675	716	Flag	579	Flag	579	Flag	586		
10 A	267	393	660	700	Flag	574	Flag	574	Flag	574		
11 A	377	403	780	828	Flag	634	Flag	634	Flag	634		
12 P	436	397	833	884	Flag	617	Flag	617	Flag	617		
1 P	442	431	873	926	Flag	615	Flag	615	Flag	615		
2 P	481	373	854	906	Flag	598	Flag	652	Flag	652		
3 P	550	463	1013	1075	Flag	645	2400					
4 P	664	479	1143	1213	Flag	705						
5 P	749	573	1322	1403	2400							
6 P	534	569	1103	1170								
7 P	395	421	816	866								
8 P	339	179	518	550							Flag	458
9 P	277	156	433	459							Flag	386
10 P	165	81	246	261							Flag	222
11 P	87	42	129	137							Flag	117
Total	6666	7041	13707	14542		6190		5324		3677		1461

Flag Summary View Period Values that differ from the Traffic Sheet are shown above in large font. They consist of:

Period Output:

- **historical demand in both directions (Vph)** = sum of historical demand in each direction. For example, 12A historical demand in both directions = 34 + 22 = 56.
- **design demand in both directions (Vph)** = design demand based on historical demand in both directions, calculated from

$$\text{design demand} = (\text{historical demand}) * \left[1 + (\text{annual traffic growth})\right]^{(\text{years of growth})} \qquad (84)$$

Method Period Input:

- **backup at start of flagging (V)** = **Bsof** = backup at the beginning of the flagging operation = backup at the end of the period that precedes flagging (default = 0 = blank). Input must immediately precede identification of the first flagging period, as shown in Method 3 above. It is usually 0, for which we can leave it blank, as in Method 1, 2, and 4.
- **flagging periods** = periods of time during which flagging is being performed. Each period is identified by the word “Flag”. (Many similar words, such as flagging, flagged, slagged, slag are also recognized.)
- **capacity at end of flagging (Vph)** = **Ceof** = the capacity of the lanes in both directions immediately after flagging ceases (default = 2400 Vph). Input must immediately

follow identification of the last flagging period, as shown above in Method 1, 2, and 3. It can also be left blank (for default = blank = 2400 Vph), as in Method 4.

Method Period Output:

- **actual demand (V/period)** = number of vehicles that arrive during the period and pass through the work zone = (design demand) – (decrease in demand) = (design demand) – [(canceled cars) + (canceled trucks) + (diverted cars) + (diverted trucks)].

The example above shows four methods:

Method 1 – "F, 7A-5P" flagging is from 7:00 am to 5:00 pm. Backup at start of flagging = default = blank = 0. Capacity at end of flagging = 2400 Vph. Actual demand varies from 556 to 667 Vph.

Method 2 – "F, 5A-3P" flagging is from 5:00 am to 3:00 pm. Backup at start of flagging = blank = default = 0. Capacity at end of flagging = 2400 Vph. Actual demand varies from 112 to 667 Vph.

Method 3 – "F, 9A-3P" flagging is from 9:00 am to 3:00 pm. Backup at start of flagging = 0. Capacity at end of flagging = blank = default = 2400 Vph. Actual demand varies from 574 to 634 Vph.

Method 4 – "Night" flagging is from 8:00 pm to 6:00 am. Backup at start of flagging = blank = default = 0. Capacity at end of flagging = blank = default = 2400 Vph. Actual demand varies from 25 to 458 Vph. Note: This method bridges from the end of 24 periods to the start of 24 periods. This is accurate only if there is no end of period backup at the end of the 24 periods. If there is backup at 12A, we must reorganize periods for this method. For example, we can input periods starting with anytime from 6A to 7P, and the flagging operation will not bridge the ends.

Flagging period input is required to explicitly identify the periods in which flagging occurs, for which we input the word "Flag" (or flag, Flagged, flagged, Flagging, flagging, etc, because COFlag recognizes any word that contains the letters "lag".) COFlag does no calculations for demand before the first "Flag" or after the last "Flag", and flagging periods must be contiguous. If flagging is performed in more than one flagging duration, such as between 7A and 10A and between 3P and 6P, then each flagging operation is a separate method. Similarly, we use the Traffic Sheet, not the Flag Sheet, to model another traffic method before or after a flagging operation.

Capacity at end of flagging is the capacity at which backup remaining at the end of flagging is relieved. The typical flagging operation consists of closing one lane of a two lane two–way road during flagging and opening the lane at the end of flagging. Therefore, the default capacity at end of flagging = capacity of a typical two lane two–way road = 1200 Vph in each direction = 2400 Vph. When there is backup, we expect flaggers to adjust gate open and closed times in each direction so (1) backup occurs in both directions (2) that dissipates in both directions in about the same length of time when a lane reopens and two–way capacity is restored. To be recognized, capacity at end of flagging must immediately follow the last "Flag" input. A blank immediately following the last "Flag" invokes default = 2400 Vph.

Generally, backup at start of flagging = 0, because flagging is rarely practical when capacity without flagging is less than demand. capacity during flagging is usually much lower than capacity during flagging. For example, flagging generally reduces capacity to 300–600 Vph. Demand rarely drops off so rapidly that flagging is practical for roads that have backups from demand > 2400 immediately before flagging is started.

However, there are instances when backup precedes flagging, such as when flagging is preceded by a short period in which both lanes are closed to set up construction. We model this in these steps:

1. On the Flag Input Sheet (or Flag Route Sheet) we calculate maximum capacity during flagging.
2. On the Traffic Sheet we model congestion that precedes flagging. For this we input a portion of the maximum capacity (usually half) for each direction for the flagging periods. (For example, if flagging will start at 8A, and maximum capacity during flagging = 450 Vph, we can input capacity = 225 Vph in each direction after 8A.
3. We determine end of period backup in each direction from the Traffic Sheet Overall View (or Traffic View or Combined View). For example, if flagging will start at 8A, we read the 7A end-of-period backup from the Overall View for a computer run in each direction. This method is approximate, because actual delays for flagging differ from without flagging, but it is accurate enough for our purposes.
4. In the 7A period on the Flag Sheet we input backup at start of flagging = sum of end-of-period backup in each direction, and we click the "Calculate" button Calculate on the Flag Summary View to calculate

4.3.3.2.4 Summary Output

SUMMARY OUTPUT traffic method	F, 7A-5P Flagging	F, 5A-3P Flagging	F, 9A-3P Flagging	F, 8P-6A Night Flagging
total user cost	$15,478	$11,061	$7,582	$1,722
user cost of delays	$9,886	$7,279	$4,990	$1,194
user cost of decreases	$5,592	$3,782	$2,593	$528
maximum backup (V)	123	62	51	0
maximum backup length (lane mi)	0.7	0.4	0.3	0.0
maximum delay (min.)	16.7	10.9	10.2	8.3
average delay, except diversions (min)	1.1	7.7	7.6	4.5
total delay, except diversions (V hr)	916	675	462	111
total vehicles canceled(V)	1227	830	569	116
total vehicles diverted (V)	1636	1106	758	154
total decrease in demand (V)	2863	1936	1327	270
% decrease in demand	32%	27%	27%	16%
delay per diverted vehicle (min)	7.3	7.3	7.3	7.3
total diversion delay (V hr)	200	135	93	19
average delay, including diversions (min)	1.0	7.6	7.6	4.8
total delay, including diversions (V hr)	1116	810	555	130
user cost / design demand	$1.06	$0.76	$0.52	$0.12
delay cost / actual demand	$1.61	$1.38	$1.37	$0.82
work zone method travel time (min.)	**2.4**	**2.4**	**2.4**	**2.4**
speed delay (min.)	**1.4**	**1.4**	**1.4**	**1.4**
maximum capacity (V/hr)	**606**	**606**	**606**	**606**
gate delay at maximum capacity (min.)	**4.0**	**4.0**	**4.0**	**4.0**
maximum gate and speed delay (min.)	**9.4**	**9.4**	**9.4**	**8.3**
maximum backup delay (min.)	**7.3**	**1.5**	**0.8**	**0.0**
Autc ON Print ON Nov OK validity of output	VALID	VALID	VALID	VALID

You can copy these values into Impact Sheet.

Flag Summary Output is the same, down to and including user cost / design demand, except that all values are reported for the total impact on both directions of travel. For example, total user cost and maximum delay values are for both directions. We have also directly input "Flagging" in place of direction, to indicate the results are not for individual directions. These variables are described in Sec. 1.5.3.2.8, pg. 1-28. Summary Output variables that are unique to the Flag Sheet are shown above in large font and are described below:

- **work zone method travel time**, **speed delay**, **maximum capacity**, and **gate delay at maximum capacity** are as calculated and shown for the Flag Input Sheet in Sec.4.3.1.4 pg. 4-9. These values are calculated directly from distance, speed, and flag operation inputs, and they are not all necessarily realized for each traffic maintenance method. For example, if demand is quite low, gate delay might never be as high as at maximum capacity.
- **maximum gate and speed delay (min)** = (maximum gate delay) + (speed delay) = maximum gate and speed delay computed by COFlag for a vehicle during the flagging operation.
- **maximum backup delay (min)** = (maximum delay) – (maximum gate and speed delay) = maximum backup delay computed by COFlag for a vehicle during the flagging operation.

4.3.3.3 Overall View

The Overall View is second only to the Summary View in importance, because it shows the traffic impact and user cost results for each period for one method for total traffic in both directions. In addition, it shows the input data on which the results are based and summary output. Therefore, the Overall View provides a complete report of input values and the detailed and summarized output for the most recent computer run, as shown in its three major elements:

- Input shows complete input for project, vehicles, methods, and periods, as transferred from the Summary View, for one traffic maintenance method.
- Period output provides computer results for demand, backup, delay, decreases in demand, and user cost for each of the 24 periods, with totals, maximums, and minimums, as appropriate.
- Summary output is the same as in the Summary View.

4.3.3.3.1 Period Output

Period Output is the same as in the Traffic Sheet Overall View, except for the following:

- All output is for the combination of both directions, COFlag does not differentiate between the directions.
- **backup at start of flagging, flagging periods,** and **capacity at end of flagging** are unique to the Flag Sheet, and they replace the capacity input of the Traffic Sheet, as described in Sec. 4.3.3.2.3.
- **average zone delay** = average gate delay + average speed delay, which replaces average speed delay of the Traffic Sheet.

4.3.3.3.2 Summary Output

The summary output is the same as in the Summary View for the traffic maintenance method used in the most recent computer run. The variables in summary output are described in Sec. 4.3.3.2.4.

4.3.3.4 Traffic, User Cost, and Combined Views

As described in Sec. 4.3.3.1, pg. 4-12, Traffic View, User Cost View, and Combined View show a subset of period output for traffic variables, user cost variables, and a more reduced subset of both traffic and user cost variables, that are internally copied from the Overall View. They also each show all the input values and Summary Output that are also shown in the Summary View and Overall View. Each of these three views provides a concentrated focus on a more limited group of variables than the Overall View. These views are practical for transparencies for presentations or otherwise focusing attention on a selected subset of important results.

These views together provide no more information that is not contained in the Overall View, but in three times as many pages, which requires three times as much printing. It is also generally easier to understand detailed output when it is all together, as in the Overall View. Therefore, we generally only print, review, and keep the Overall Views, together with the Summary View. We only print the Traffic, User Cost, and Combined Views when there is a specific reason to do so. These views are not shown here, because they do not differ from the Traffic Sheet views shown in Sec. 1.5.3.4, pg. 1-36 except as described in Sec. 4.3.3.3.1.

Overall View - Flagging Operation

period length (min)	60	
annual traffic growth (%)	3.00%	
years of growth	2	
VEHICLE INPUT	cars	trucks
design demand (%)	98.0%	2.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.20	
METHOD INPUT	METHOD 1	
method title	F, 7A-5P	
DISTANCE AND SPEED (mi) (mph)	distance	speed
work zone — method travel	1.0	25
work zone — normal travel	1.0	60
diversion — method travel	10.0	45
diversion — normal travel	6.0	60
SPEED DELAY INPUT		
vehicle headway at gate (sec)	3	
dead time at gate when direction changes (sec)	15	
allowable gate closed time (min.)	8	
DECREASE TO DEMAND INPUT		
canceled cars (with no delay) (%)		
canceled trucks (with no delay) (%)		
canceled cars (with delay) (%/min)	1.5%	
canceled trucks (with delay) (%/min)		
diverted cars (with no delay) (%)		
diverted trucks (with no delay) (%)		
diverted cars (with delay) (%/min)	2.0%	
diverted trucks (with delay) (%/min)		
OTHER USER COST INPUT	cars	trucks
other user cost per actual demand ($/V)	$0.00	$0.00
user cost per diversion ($/V)	$2.52	$5.32

PROJECT INFORMATION	
PROJECT TITLE	M-43 Overlay Zimmer to Cornell
C.S.	33082
JOB #	36569A
START DATE	April, 1995

REPORT INFORMATION	
REPORT TITLE	DETAILED USER COST REPORT OVERALL VIEW
DIVISION	
REPORT BY	
REPORT DATE	4/1/94

SUMMARY OUTPUT — traffic method	F, 7A-5P
total user cost	$15,478
user cost of delays	$9,886
user cost of decreases	$5,592
maximum backup (V)	123
maximum backup length (lane mi)	0.7
maximum delay (min.)	16.7
average delay, except diversions (min)	9.0
total delay, except diversions (V hr)	916
total vehicles canceled(V)	1227
total vehicles diverted (V)	1636
total decrease in demand (V)	2863
% decrease in demand	32%
delay per diverted vehicle (min)	7.3
total diversion delay (V hr)	200
average delay, including diversions (min)	8.6
total delay, including diversions (V hr)	1116
user cost / design demand	$1.06
delay cost / actual demand	$1.61
work zone method travel time (min.)	2.4
speed delay (min.)	1.4
maximum capacity (V/hr)	606
gate delay at maximum capacity (min.)	4.0
maximum gate and speed delay (min.)	9.4
maximum backup delay (min.)	7.3

Overall | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

period (hr)	hist. demand (V/period)	design demand (V/period)	Flag	actual demand (V/period)	backup eop (V)	backup length eop (lane.mile)	maximum delay (min)	total period delay (Vhr)	average backup delay (min)	average zone delay (min)	average delay (min)		user cost / total vehicles ($/V)	delay cost / actual demand ($/V)
12 A	56	59												
1 A	29	31												
2 A	29	31												
3 A	27	29												
4 A	42	45												
5 A	123	130												
6 A	355	377												
7 A	886	940	Flag	667	62	0.35	10.95	94	3.06	5.40	8.46		$1.65	$1.52
8 A	762	808	Flag	556	13	0.07	7.51	84	3.69	5.40	9.09		$1.73	$1.63
9 A	675	716	Flag	579	0	0.00	10.65	54	0.26	5.33	5.59		$1.19	$1.01
10 A	660	700	Flag	574	0	0.00	9.13	50	0.00	5.27	5.27		$1.13	$0.95
11 A	780	828	Flag	634	29	0.16	8.10	72	1.41	5.40	6.81		$1.40	$1.23
12 P	833	884	Flag	617	40	0.23	9.29	90	3.40	5.40	8.80		$1.69	$1.58
1 P	873	926	Flag	615	49	0.28	10.18	100	4.41	5.40	9.81		$1.83	$1.76
2 P	854	906	Flag	598	42	0.24	9.59	99	4.50	5.40	9.90		$1.84	$1.78
3 P	1013	1075	Flag	645	81	0.46	13.22	125	6.26	5.40	11.66		$2.04	$2.10
4 P	1143	1213	Flag	647	123	0.70	16.73	147	9.21	4.38	13.60		$2.22	$2.44
5 P	1322	1403	2400											
6 P	1103	1170												
7 P	816	866												
8 P	518	550												
9 P	433	459												
10 P	246	261												
11 P	129	137												
TOT	13707	14542	2400	6,133				916				AVG	$1.06	$1.61
MAX	1322	1403	2400	667	123	0.70	16.73	147	9.21	5.40	13.60	MAX	$2.22	$2.44
MIN	27	29	2400	556	0	0.00	7.51	50	0	4.38	5.27	MIN	$1.13	$0.95

Overall | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

period (hr)	canceled cars (V)	canceled trucks (V)	diverted cars (V)	diverted trucks (V)	decrease to cars (V/period)	decrease to trucks (V/period)	total period decrease (V/period)	decrease cost cars ($)	decrease cost trucks ($)	delay cost cars ($)	delay cost trucks ($)	decrease cost ($)	delay cost ($)	user cost ($)
12 A														
1 A														
2 A														
3 A														
4 A														
5 A														
6 A														
7 A	117	0	156	0	273	0	273	$533	$0	$986	$29	$533	$1,015	$1,547
8 A	108	0	144	0	252	0	252	$492	$0	$883	$26	$492	$909	$1,401
9 A	59	0	78	0	137	0	137	$268	$0	$567	$14	$268	$582	$850
10 A	54	0	72	0	126	0	126	$247	$0	$530	$13	$247	$543	$790
11 A	83	0	110	0	193	0	193	$378	$0	$757	$20	$378	$777	$1,155
12 P	114	0	152	0	267	0	267	$521	$0	$948	$28	$521	$976	$1,497
1 P	134	0	178	0	312	0	312	$609	$0	$1,051	$33	$609	$1,084	$1,693
2 P	132	0	176	0	308	0	308	$601	$0	$1,033	$32	$601	$1,065	$1,666
3 P	184	0	246	0	430	0	430	$839	$0	$1,307	$45	$839	$1,352	$2,192
4 P	242	0	323	0	565	0	565	$1,105	$0	$1,523	$59	$1,105	$1,582	$2,687
5 P														
6 P														
7 P														
8 P														
9 P														
10 P														
11 P														
TOT	1,227	0	1,636	0	2,863	0	2,863	$5,592	$0	$9,585	$300	$5,592	$9,886	$15,478
MAX	242	0	323	0	565	0	565	$1,105	$0	$1,523	$59	$1,105	$1,582	$2,687
MIN	54	0	72	0	126	0	126	$247	$0	$530	$13	$247	$543	$790

Fig. 4-7 Flag Sheet Overall View

4.3.4 IMPACT SHEET (IMPACT TAB)

4.3.4.1 General

The Impact Sheet, also called the Impact Summary Sheet, reports daily user cost, total user cost, construction cost, and total project cost including user cost for different methods of maintaining traffic. Its purpose is to show in one place a summary of traffic, user cost, and construction cost so we can understand the overall impact of each method of maintaining traffic. The Impact Sheet used for COFlag is no different from that in CO.xls, which is described in Sec. 1.5.5, pg. 1-54. Fig. 4-8 shows an example of the Impact Sheet computer screen for a flagging operation. The shaded upper portion is for input of values from the Output Summary of the Summary View of the Traffic Sheet and from the Summary portion of the Construction Sheet. This portion is not normally printed. As with other worksheets, the Impact Sheet contains control buttons and background instructions that are for our computer use but are not printed.

The lower portion is the part that is normally printed as a report, and much of its output is not reported anywhere else. Its values are calculated from input into the upper portion, using equations in the cells of the lower portion. We must not input data directly into the lower portion or delete values that it reports, because doing so will delete the equations in its cells.

4.3.4.2 Summary Input

We Copy and Paste Values the following:

- Traffic Summary Input is Copied from Summary Output at the bottom of the Summary View of the Flag Sheet and Paste Valued into the left column for each method in the Impact Sheet. (See Sec. 4.3.3.2.4, pg. 4-20)
- Construction Summary Input is from the Summary at the bottom of the Construction Cost Sheet. (See Sec. 1.5.4.6.2, pg. 1-53. The Construction Cost Sheet from which the Construction Summary Input of Fig. 4-1.

For each traffic maintenance and construction method, we can easily Copy and Paste Values from the Summary View and the Construction Cost Sheet directly into the Impact Sheet. These variables are explained at the points referenced above, and they are not explained here. The appropriate areas from which the inputs are copied and to which they are pasted are marked by text boxes in the Summary View of the Traffic Sheet, Construction Cost Sheet, and Summary Input of the Impact Sheet.

Summary Output from a flagging operation is for the combination of two directions, and direction has no meaning. Therefore, in the Summary Output in the Summary View we have input **direction = "Flagging"**, which is also pasted into the Impact Sheet. We must input **% closed = 100%** to indicate to Impact Sheet calculations that all values are taken from the left column for the method.

IMPACT SUMMARY SHEET

SUMMARY SHEET INPUT — Project: **M-43 Overlay, Zimmer to Cornell**

By:

Other:

Copy This Sheet

Paste Values

PASTE VALUES only from Summary View of Traffic Sheet. Use DELETE to undo.

TRAFFIC SUMMARY INPUT — % closed	100%	0%	100%	0%	100%	0%	100%	0%
traffic method	F, 7A-5P		F, 5A-3P		F, 9A-3P		F, 8P-6A Night	
direction	Flagging		Flagging		Flagging		Flagging	
total user cost ($)	$15,478		$11,061		$7,582		$1,722	
user cost of delays ($)	$9,886		$7,279		$4,990		$1,194	
user cost of decreases ($)	$5,592		$3,782		$2,593		$528	
maximum backup (V)	123		62		51		0	
maximum backup length (lane mi)	0.7		0.4		0.3		0.0	
maximum delay (min.)	16.7		10.9		10.2		8.3	
average delay (min)	9.0		7.7		7.6		4.5	
total delay, except diversions (V hr)	916		675		462		111	
total vehicles canceled (V)	1227		830		569		116	
total vehicles diverted (V)	1636		1106		758		154	
total decrease in demand (V)	2863		1936		1327		270	
% decrease in demand	31.8%		26.8%		26.8%		15.6%	
delay per diverted vehicle (min)	7.3		7.3		7.3		7.3	
total diversion delay (V hr)	200		135		93		19	
average delay, including diversions (min)	8.6		7.6		7.6		4.8	
total delay, including diversions (V hr)	1116		810		555		130	
user cost / design demand ($/V)	$1.06		$0.76		$0.52		$0.12	
delay cost / actual demand ($/V)	$1.61		$1.38		$1.37		$0.82	

Paste Values

PASTE VALUES only from Construction Sheet. Use DELETE to undo.

CONSTRUCTION SUMMARY INPUT	F, 7A-5P		F, 5A-3P		F, 9A-3P		F, 8P-6A Nightwork	
lane closed hours per day (hr/day)	10		10		6		10	
lane closed days (day)	12.0		12.0		24.0		14.1	
labor cost ($)	$82,500		$82,500		$165,000		$97,059	
project cost ($)	$275,000		$275,000		$360,380		$301,806	

Copy This Sheet

Print Summary of Impacts for 4 methods, vertical

SUMMARY OF IMPACTS — **M-43 Overlay, Zimmer to Cornell**

By:

Other:

Do not change or copy in summaries below this area

Do not change these areas or copy into these areas.

USER COST, DAILY — traffic method	F, 7A-5P	F, 5A-3P	F, 9A-3P	F, 8P-6A Night
total user cost, daily ($)	$15,478	$11,061	$7,582	$1,722
user cost of delays, daily ($)	$9,886	$7,279	$4,990	$1,194
user cost of decreases , daily ($)	$5,592	$3,782	$2,593	$528
total delay, except diversions, daily (V hr)	916	675	462	111
total vehicles canceled, daily (V)	1,227	830	569	116
total vehicles diverted, daily (V)	1,636	1,106	758	154
total decrease in demand, daily (V)	2,863	1,936	1,327	270
total diversion delay, daily (V hr)	200	135	93	19
total delay, including diversions, daily (V hr)	1,116	810	555	130
USER COST, TOTAL				
total user cost ($)	$185,737	$132,727	$181,975	$24,308
user cost of delays ($)	$118,628	$87,347	$119,749	$16,859
user cost of decreases ($)	$67,109	$45,379	$62,226	$7,449
maximum backup (V)	123	62	51	0
maximum backup length (lane mi)	0.7	0.4	0.3	0.0
maximum delay (min.)	16.7	10.9	10.2	8.3
average delay, except diversions (min)	9.0	7.7	7.6	4.5
total delay, except diversions (V hr)	2,399	1,622	2,225	266
total vehicles canceled (V)	14,722	9,955	13,651	1,634
total vehicles diverted (V)	19,629	13,274	18,201	2,179
total decrease in demand (V)	34,352	23,229	31,852	3,813
% decrease in demand	31.8%	26.8%	26.8%	15.6%
average delay per diverted vehicle (min)	7.3	7.3	7.3	7.3
total diversion delay (V hr)	2,399	1,622	2,225	266
average delay, including diversions (min)	8.6	7.6	7.6	4.8
total delay, including diversions (V hr)	13,393	9,718	13,323	1,829
average user cost / design demand ($/V)	$1.06	$0.76	$0.52	$0.12
average delay cost / actual demand ($/V)	$1.61	$1.38	$1.37	$0.82
CONSTRUCTION COST — method	F, 7A-5P	F, 5A-3P	F, 9A-3P	F, 8P-6A Nightwork
lane closed hours per day (hr/day)	10	10	6	10
lane closed days (day)	12.0	12.0	24.0	14.1
labor cost ($)	$82,500	$82,500	$165,000	$97,059
project cost ($)	$275,000	$275,000	$360,380	$301,806
TOTAL PROJECT COST	**$460,737**	**$407,727**	**$542,355**	**$326,114**

Fig. 4-8 Impact Sheet for Flagging Operation

4.3.5 DAILY COST SHEET (DAILY TAB)

4.3.5.1 General

The Daily Cost Sheet calculates daily traffic user cost for any set of traffic maintenance hours, for any cost round-off and for fractions of periods. COFlag uses the same Daily Sheet in the same way as CO^3, as described in Sec. 1.7.2, pg. 1-65. Fig. 4-10 is a Flag Sheet Combined View for 24 hours of flagging, which parallels Fig. 1-17, pg. 1-69 for CO^3. The only difference between COFlag and CO^3 Daily Sheet use, is that for COFlag we input the user cost for the combination of two directions. For CO^3 we input either the user cost for the average of two directions, or a user cost for each direction. Fig. 4-9 is a User Cost View and a Period Cost View from a Daily Sheet for the 24 hours of user costs that we Copied and Paste Valued from Fig. 4-10. These demonstrate that the Daily Cost Sheet is used the same way for flagging as for normal one-way travel in each lane. The other Daily Cost Sheet views are not shown for flagging, because they are identical in their use to those in Chapter 1.

User Cost View — Paste Values

Project:	M-43 Overlay	
By:		
Other:		
Method:	Flagging	
Traffic:	Alternating 1-way	
Print	User Cost per Period	
Period (min):	60	15
12 A - 1 A	$54	$14
1 A - 2 A	$28	$7
2 A - 3 A	$28	$7
3 A - 4 A	$26	$6
4 A - 5 A	$40	$10
5 A - 6 A	$121	$30
6 A - 7 A	$373	$93
7 A - 8 A	$1,547	$387
8 A - 9 A	$1,401	$350
9 A - 10 A	$850	$212
10 A - 11 A	$790	$198
11 A - 12 P	$1,155	$289
12 P - 1 P	$1,497	$374
1 P - 2 P	$1,693	$423
2 P - 3 P	$1,666	$417
3 P - 4 P	$2,192	$548
4 P - 5 P	$2,746	$687
5 P - 6 P	$3,329	$832
6 P - 7 P	$2,718	$680
7 P - 8 P	$1,654	$414
8 P - 9 P	$609	$152
9 P - 10 P	$468	$117
10 P - 11 P	$250	$62
11 P - 12 A	$127	$32
24 hr	$25,363	

Adjustments to User Cost

Fraction = P/U =		**35%**
Cost Threshold =		**$100**
Round-Off =	**$10**	

Period Cost View

Project:	M-43 Overlay	
By:		
Other:		
Method:	Flagging	
Traffic:	Alternating 1-way	
Print	Cost per Period	
Period (min):	60	15
12 A - 1 A	$0	$0
1 A - 2 A	$0	$0
2 A - 3 A	$0	$0
3 A - 4 A	$0	$0
4 A - 5 A	$0	$0
5 A - 6 A	$0	$0
6 A - 7 A	$130	$33
7 A - 8 A	$540	$135
8 A - 9 A	$490	$123
9 A - 10 A	$300	$75
10 A - 11 A	$280	$70
11 A - 12 P	$400	$100
12 P - 1 P	$520	$130
1 P - 2 P	$590	$148
2 P - 3 P	$580	$145
3 P - 4 P	$770	$193
4 P - 5 P	$960	$240
5 P - 6 P	$1,170	$293
6 P - 7 P	$950	$238
7 P - 8 P	$580	$145
8 P - 9 P	$210	$53
9 P - 10 P	$160	$40
10 P - 11 P	$0	$0
11 P - 12 A	$0	$0
24 hr	$8,630	

Fig. 4-9 Daily Sheet: User Cost View and Period Cost View

Combined View - Flagging Operation

period length (min)	60	
annual traffic growth (%)	0	
years of growth	2	
VEHICLE INPUT	cars	trucks
design demand (%)	98.0%	2.0%
user cost per hour ($/V hr)	$10.79	$10.79
user cost per mile, ($/V mi)	$0.30	$1.00
user cost per cancellation, ($/V)	$1.20	
METHOD INPUT	METHOD 1	
method title	24 hr flagging	
DISTANCE AND SPEED (mi) (mph)	distance	speed
work zone method travel	1.0	25
work zone normal travel	1.0	60
diversion method travel	10.0	45
diversion normal travel	6.0	60
SPEED DELAY INPUT		
vehicle headway at gate (sec)	3	
dead time at gate when direction changes (sec)	15	
allowable gate closed time (min.)	8	
DECREASE TO DEMAND INPUT		
canceled cars (with no delay) (%)		
canceled trucks (with no delay) (%)		
canceled cars (with delay) (%/min)	1.5%	
canceled trucks (with delay) (%/min)		
diverted cars (with no delay) (%)		
diverted trucks (with no delay) (%)		
diverted cars (with delay) (%/min)	2.0%	
diverted trucks (with delay) (%/min)		
OTHER USER COST INPUT	cars	trucks
other user cost per actual demand ($/V)	$0.00	$0.00
user cost per diversion ($/V)	$2.52	$5.32

PROJECT INFORMATION	
PROJECT TITLE	M-43 Overlay Zimmer to Cornell
C.S.	33082
JOB #	36569A
START DATE	April, 1995

REPORT INFORMATION	
REPORT TITLE	DETAILED USER COST REPORT COMBINED VIEW
DIVISION	
REPORT BY	
REPORT DATE	4/1/94

SUMMARY OUTPUT traffic method	24 hr flagging
total user cost	$25,363
user cost of delays	$15,760
user cost of decreases	$9,603
maximum backup (V)	120
maximum backup length (lane mi)	0.7
maximum delay (min.)	16.8
average delay, except diversions (min)	9.1
total delay, except diversions (V hr)	1461
total vehicles canceled(V)	2107
total vehicles diverted (V)	2809
total decrease in demand (V)	4915
% decrease in demand	34%
delay per diverted vehicle (min)	7.3
total diversion delay (V hr)	343
average delay, including diversions (min)	8.7
total delay, including diversions (V hr)	1804
user cost / design demand	$0.00
delay cost / actual demand	$0.00
work zone method travel time (min.)	2400.0
speed delay (min.)	0.0
maximum capacity (V/hr)	0
gate delay at maximum capacity (min.)	0.0
maximum gate and speed delay (min.)	0.0
maximum backup delay (min.)	0.0

Combo | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

Direction: period (hr)	Flag	backup at start (V) actual demand (V/period)	total decrease (V/period)	total delay (V hr)	backup eop (V)	maximum delay (min)	average backup delay (min)	average zone delay (min)	decrease cost ($)	delay cost ($)	user cost ($)	delay cost / actual demand ($/V)
12 A	Flag	51	8	3	0	4.11	0.0	4.1	$16	$38	$54	$0.74
1 A	Flag	26	4	2	0	4.08	0.0	4.1	$8	$19	$28	$0.73
2 A	Flag	26	4	2	0	4.08	0.0	4.1	$8	$19	$28	$0.73
3 A	Flag	25	4	2	0	4.08	0.0	4.1	$8	$18	$26	$0.73
4 A	Flag	38	6	3	0	4.09	0.0	4.1	$12	$28	$40	$0.74
5 A	Flag	112	19	8	0	4.19	0.0	4.2	$37	$84	$121	$0.75
6 A	Flag	318	58	24	0	4.53	0.0	4.5	$114	$259	$373	$0.81
7 A	Flag	667	273	94	62	10.95	3.1	5.4	$533	$1,015	$1,547	$1.52
8 A	Flag	556	252	84	13	7.51	3.7	5.4	$492	$909	$1,401	$1.63
9 A	Flag	579	137	54	0	6.65	0.3	5.3	$268	$582	$850	$1.01
10 A	Flag	574	126	50	0	5.27	0.0	5.3	$247	$543	$790	$0.95
11 A	Flag	634	193	72	29	8.10	1.4	5.4	$378	$777	$1,155	$1.23
12 P	Flag	617	267	90	40	9.29	3.4	5.4	$521	$976	$1,497	$1.58
1 P	Flag	615	312	100	49	10.18	4.4	5.4	$609	$1,084	$1,693	$1.76
2 P	Flag	598	308	99	42	9.59	4.5	5.4	$601	$1,065	$1,666	$1.78
3 P	Flag	645	430	125	81	13.22	6.3	5.4	$839	$1,352	$2,192	$2.10
4 P	Flag	620	593	147	96	14.80	8.8	5.4	$1,158	$1,589	$2,746	$2.56
5 P	Flag	630	773	169	120	16.80	10.7	5.4	$1,510	$1,819	$3,329	$2.89
6 P	Flag	563	607	142	77	13.59	9.7	5.4	$1,187	$1,532	$2,718	$2.72
7 P	Flag	554	312	97	25	9.01	5.1	5.4	$609	$1,046	$1,654	$1.89
8 P	Flag	452	97	39	0	7.91	0.2	4.9	$190	$419	$609	$0.93
9 P	Flag	386	74	30	0	4.68	0.0	4.7	$144	$324	$468	$0.84
10 P	Flag	222	39	16	0	4.35	0.0	4.4	$76	$174	$250	$0.78
11 P	Flag	117	20	8	0	4.19	0.0	4.2	$38	$88	$127	$0.75
TOT	0	9,626	4,915	1,461					$9,603	$15,760	$25,363	$2
MAX	0	667	773	169	120	16.80	11	5.40	$1,510	$1,819	$3,329	$3
MIN	0	25	4	2	0	4.08	0	4.08	$8	$18	$26	$1

Fig. 4-10 Flag Sheet Combined View

4.4 FLAGGING GUIDELINES

4.4.1 OVERVIEW OF COFLAG

4.4.1.1 Recap of COFlag System

We have now determined the impacts of various flagging operations and construction methods on congestion and user cost during the project, following this sequence, where the Standard Method to maintain traffic during construction is flagging:

- We use the Flag Input Sheet to estimate and record project variables that impact traffic and user cost, particularly for the method of traffic maintenance by which the work would typically be done, which we often call the Standard Method or Standard Case.
- If we want to consider multiple alternate routes, or if the alternate route is complex, we use the Flag Route Sheet to calculate equivalent values for input into the Summary View.
- We enter values in the Summary View of the Flag Sheet for the Standard Method and calculate traffic and user cost impact for each day of construction. Generally, we print the Overall View for each computer run. This allows us to study the impact in detail, to understand traffic impact for each hour of a day's construction. If the traffic and user cost impacts are acceptable, we can stop our study here. However, we might still go a little further, to see if some small adjustments might reduce impacts even further.
- We identify alternative methods of maintaining traffic during construction, and for each of them we estimate and enter values in the Summary View of the Flag Sheet (or the Traffic Sheet if an alternative uses one-way travel in each lane rather than flagging), and we calculate and study their impacts.
- If we expect the different methods of maintaining traffic can impact construction contract cost, we use the Construction Cost Sheet. We use this as a guide and a calculator for our estimation of construction costs for alternative traffic maintenance and construction methods. (See Sec. 1.5.4, pg. 1-42.)
- We copy traffic, user cost, and construction cost impacts from the Summary View(s) of the Flag Sheet (and Traffic Sheet for one-way traffic in a lane) and Construction Cost Sheet to the Impact Sheet. For each method, the Impact Sheet calculates and reports overall daily traffic and user cost impact for each day of construction and total traffic, user cost, and construction cost for the complete project.
- We use the results from earlier calculations to help us identify and fine-tune alternative methods, for each of which we calculate impacts as described above.
- To our earlier knowledge of project needs, we add what we learn from our CO^3 study of the project. We apply our engineering judgment to all we know about the project, including what we have learned using CO^3. We select a traffic maintenance and construction method that has a good, acceptable, practical balance among construction needs and costs and traffic and user cost impact.

The results in the Impact Sheet in Fig. 4-8, pg. 4-25, provide an example of COFlag output. The methods identified are the following:

Method 5 – "F, 7A-5P" – This is the Standard Method: Close a lane and work 10 hours per day, from 7A-5P each day, with flagging in the other lane.

Method 6 – "F, 5A-3P" – Same as Method 1, except start and finish work 2 hours earlier each day.

Method 7 – "F, 9A-3P" – Same as Method 1, except work 6 hours from 9A-3P each day to avoid rush hours.

Method 8 – "F, 8P-6A Night" – Same as Method 1, except work 10 hours from 8P-6A at night to avoid day traffic.

Our use of COFlag has shown the Standard Method has major impact. User cost = $186,000 which is 67% of contract cost = $275,000. Average delay = 8.6 min for all vehicles, including diversion delay, total delay = 13,400 V-hr, and we estimate average user cost per vehicle = $1.06. We expect daily backups of 123 vehicles, 0.7 miles long. This indicates we should look for a better way of doing the work.

One alternative is to start and finish 2 hours earlier, to avoid the afternoon rush hour, which is heavier than the morning rush hour. This reduces user cost by $53,000, to $133,000; total delay by 3,700 V-hr, to 9,700 V-hr; and average delay by 1.0 min to 7.6 min. Another alternative is to work 6 hours instead of 10 hours to avoid rush hours. This doubles the lane-closed days to 24 without significant impact on user cost or delay, and we estimate it will raise contract cost by $85,000. Therefore, this is not practical. A third alternative is to work at night to avoid day traffic. This reduces traffic impact to user cost = $24,000, and total delay = 1,800 V-hr, which are not significant. Nighttime work increases estimated contract amount to project cost = $302,000. Therefore, nighttime work is estimated to reduce user cost by $162,000 at an increase in contract amount of $27,000, a yield of 162,000 / 27,000 = 6, which is a bargain. Therefore, of these alternative methods, we prefer nighttime work if it is otherwise practical.

4.4.1.2 Sensitivity Analysis

4.4.1.2.1 General

Sensitivity analysis is calculation of differences in output due to differences in input. Sensitivity analysis is particularly important for COFlag, because we find that capacity, traffic impact, and user cost is quite sensitive to values of flagging operation variables. Good project planning and flagging management can substantially reduce the impact of construction on users. Conversely, poor project planning or flagging management can change an acceptable project into a monster.

4.4.1.2.2 Sensitivity to Speed, Length, Dead Time, and Headway

Fig. 4-11 is a Summary View of sensitivity analysis to determine the impact of higher work zone method speed, shorter work zone distance, less dead time, and less headway. All of the four methods are the same as Method 1 in Fig. 4-6, pg. 4-17, except for a change in one variable. Each change is marked by an ellipse so it is easy for us to see. Fig. 4-13 shows the values for the Standard Method, "F, 7A-5P" in Fig. 4-6 and the values for the methods in Fig. 4-11 and their differences from the Standard Method. This simple sensitivity analysis shows us the following, when compared to the Standard Method "F, 7A-5P" in Fig. 4-6:

- **Increasing Speed: Faster, 7-5 -** work zone method speed = 35 mph, an increase of 40% versus 25 mph. This reduces user cost by 36% to $9,665 / day, speed delay by 49%, total delay by 35% to 722 V-hr, average delay by 26% to 6.4 min, decrease in demand by 46% to 14% of design demand, and maximum backup by 35% to 79 V. Increasing speed not only reduces speed delay, but it also decreases the time vehicles have to wait on traffic from the opposite direction.

- **Decreasing Length: Shorter, 7-5** - work zone distance = 0.75 mi, a decrease of 25% versus 1.0 mi. This reduces user cost by 33% to $10,379 / day, speed delay by 25%, total delay by

31% to 775 V-hr, average delay by 35% to 5.6 min, decrease in demand by 41% to 19% of design demand, and maximum backup by 34% to 81 V. Like increasing speed, decreasing work zone distance not only reduces speed delay, but it also decreases the time vehicles have to wait on traffic from the opposite direction.

- **Decreasing Dead Time: Less dead time, 7-5 –** dead time = 5 sec, a decrease of 67% versus 15 sec. This reduces user cost by 11% to $13,817 / day, total delay by 10% to 1,009 V-hr, average delay by 12% to 7.6 min, decrease in demand by 15% to 27% of design demand, and maximum backup by 11% to 109 V.
- **Decreasing Headway: Less headway, 7-5 –** headway = 2.5 sec, a decrease of 17% versus 3.0 sec. This reduces user cost by 23% to $11,970 / day, total delay by 21% to 884 V-hr, average delay by 24% to 6.5 min, decrease in demand by 29% to 22% of design demand, and maximum backup by 25% to 92 V.

These results demonstrate the importance of maintaining good driving conditions within the work zone so traffic speed can be maintained; keeping the zone length as short as possible, even if the zone must be moved during the day; keeping dead time as low as possible, through flagger communication and management of equipment and workers in the zone so they do not require dead time; and good management of gate conditions, so traffic will enter the zone quickly and reduce headway.

4.4.1.2.3 Sensitivity to Allowable Gate Closed Time

Fig. 4-12 is a Summary View of sensitivity analysis to determine the impact of different allowable gate closed times. All of the four methods are the same as Method 1 in Fig. 4-6, pg. 4-17, except for a change in allowable gate closed time, which is marked by an ellipse so it is easy for us to see. The Standard Method allowable gate closed time = 8 min, and Fig. 4-12 shows impact of 6, 10, 12, and 15 min values. Fig. 4-14 shows the values for the Standard Method, “F, 7A-5P” in Fig. 4-6 and the values for the methods in Fig. 4-12 and their differences from the Standard Method. This simple sensitivity analysis shows us the following, when compared to the Standard Method “F, 7A-5P” in Fig. 4-6:

- **allowable gate closed time = 6 min** increases user cost by 42% to $22,042 / day, maximum delay by 85% to 30.9 min, total delay by 20% to 1,336 V-hr, and maximum backup by 5% to 129 V. Cancellations, diversions, and total decrease in demand all increase by 122%, to 2725, 3633, and 6358 V, which is 71% of design demand. Therefore, only 29% of design demand will travel through the zone. Obviously, this is much worse than allowable gate closed time = 8 min.
- **allowable gate closed time = 10 min** decreases user cost by 22% to $12,052 / day, maximum delay by 28% to 12.1 min, total delay by 20% to 892 V-hr, and maximum backup by 44% to 69 V. Cancellations, diversions, and total decrease in demand all decrease by 29%, to 866, 1155, and 2021 V, which is 22% of design demand. Maximum capacity is increased by 27% to 767 Vph. Everything is substantially better than when allowable gate closed time = 8 min, so we obviously prefer allowable gate closed time = 10 min.
- **allowable gate closed time = 12 min** decreases user cost by 25% to $11,611 / day, maximum delay by 25% to 12.5 min, total delay by 22% to 866 V-hr, and maximum backup by 83% to 21 V. Cancellations, diversions, and total decrease in demand all decrease by 33%, to 824,

1099, and 1923 V, which is 21% of design demand. Maximum capacity is increased by 42% to 860 Vph. Everything is substantially better than when allowable gate closed time = 8 min, and a little better than when allowable gate closed time = 10 min, so we slightly prefer allowable gate closed time = 12 min.

- **allowable gate closed time = 15 min** decreases user cost by 25% to $11,647 / day, maximum delay by 15% to 14.2 min, total delay by 23% to 863 V-hr, and maximum backup by 100% to 0 V. Cancellations, diversions, and total decrease in demand all decrease by 33%, to 821, 1094, and 1915 V, which is 21% of design demand. Maximum capacity is increased by 56% to 943 Vph. Maximum capacity is increased a little over allowable gate closed time = 12 min, which eliminates backup, but this was unimportant at allowable gate closed time = 12 min. Nothing else benefited significantly, but maximum delay was increased from 12.5 min to 14.2 min. Therefore, we prefer allowable gate closed time = 12 min.

Our general flagging policy, as stated earlier is to open a gate until all vehicles waiting can enter the zone, then close it against stragglers that are not yet at the gate. We do this until the average gate closed time for the two gates will exceed the allowable gate closed time. At this point we limit gate closed time so the average of the two gates equals the allowable gate closed time, with relative gate open time of each gate proportional to its demand. We see from this sensitivity analysis that allowable gate closed time is an important variable to select, and COFlag gives us a good tool with which to select it.

SummaryView - Flagging Operation

Copy This Sheet	period length (min)	60		
	annual traffic growth (%)	3.00%		
Update	years of growth	2		
VEHICLE INPUT		cars	trucks	
	design demand (%)	98.0%	2.0%	
	user cost per hour ($/V hr)	$10.79	$10.79	
	user cost per mile, ($/V mi)	$0.30	$1.00	
	user cost per cancellation, ($/V)	$1.20		

PROJECT INFORMATION	
PROJECT TITLE	M-43 Overlay Zimmer to Cornell
Paste Values C.S.	33082
JOB #	36569A
START DATE	April, 1995
NOTES:	

REPORT INFORMATION	
REPORT TITLE	DETAILED USER COST REPORT SUMMARY VIEW
DIVISION	
REPORT BY	
REPORT DATE	4/1/94

METHOD INPUT		METHOD 1		METHOD 2		METHOD 3		METHOD 4	
	method title	Faster, 7-5		Shorter, 7-5		Less dead time, 7-5		Less headway, 7-5	
DISTANCE AND SPEED INPUTS	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	1.0	35	0.75	25	1.0	25	1.0	25
	normal travel	1.0	60	0.75	60	1.0	60	1.0	60
diversion	method travel	10.0	45	10.0	45	10.0	45	10.0	45
	normal travel	6.0	60	6.0	60	6.0	60	6.0	60
FLAG OPERATION INPUTS									
	vehicle headway at gate (sec)	3		3		3		2.5	
	dead time at gate when direction changes (sec)	15		15		5		15	
	allowable gate closed time (min.)	8		8		8		8	
DECREASE TO DEMAND									
	canceled cars (with no delay) (%)								
	canceled trucks (with no delay) (%)								
	canceled cars (with delay) (%/min)	1.5%		1.5%		1.5%		1.5%	
	canceled trucks (with delay) (%/min)								
	diverted cars (with no delay) (%)								
	diverted trucks (with no delay) (%)								
	diverted cars (with delay) (%/min)	2.0%		2.0%		2.0%		2.0%	
	diverted trucks (with delay) (%/min)								
OTHER USER COST INPUT	Update	cars	trucks	cars	trucks	cars	trucks	cars	trucks
	other user cost per actual demand ($/V)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	user cost per diversion ($/V)	$2.52	$5.32	$2.52	$5.32	$2.52	$5.32	$2.52	$5.32
	Paste Values	Calculate		Calculate		Calculate		Calculate	

Summary | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

PERIOD VALUES (V/period) — (Backup at Start of Flagging) Flag Periods (Capacity at End of Flagging) Demand

direction:	E	W	Both Directions		(Bsof) Flag	demand	(Bsof) Flag	demand	(Bsof) Flag	demand	(Bsof) Flag	demand
period		historical		design	(Ceof)	actual	(Ceof)	actual	(Ceof)	actual	(Ceof)	actual
12 A	34	22	56	59								
1 A	15	14	29	31								
2 A	17	12	29	31								
3 A	19	8	27	29								
4 A	15	27	42	45								
5 A	32	91	123	130								
6 A	90	265	355	377								
7 A	227	659	886	940	Flag	792	Flag	779	Flag	703	Flag	737
8 A	234	528	762	808	Flag	696	Flag	685	Flag	611	Flag	662
9 A	220	455	675	716	Flag	624	Flag	614	Flag	591	Flag	594
10 A	267	393	660	700	Flag	611	Flag	601	Flag	579	Flag	581
11 A	377	403	780	828	Flag	711	Flag	699	Flag	664	Flag	679
12 P	436	397	833	884	Flag	752	Flag	740	Flag	680	Flag	721
1 P	442	431	873	926	Flag	782	Flag	769	Flag	669	Flag	735
2 P	481	373	854	906	Flag	768	Flag	755	Flag	652	Flag	719
3 P	550	463	1013	1075	Flag	848	Flag	829	Flag	707	Flag	785
4 P	664	479	1143	1213	Flag	850	Flag	825	Flag	695	Flag	760
5 P	749	573	1322	1403	2400		2400		2400		2400	
6 P	534	569	1103	1170								
7 P	395	421	816	866								
8 P	339	179	518	550								
9 P	277	156	433	459								
10 P	165	81	246	261								
11 P	87	42	129	137								
Total	6666	7041	13707	14542		7436		7295		6551		6973

SUMMARY OUTPUT	traffic method	Faster, 7-5	Shorter, 7-5	Less dead time, 7-5	Less headway, 7-5
SUMMARY OUTPUT	traffic method	Faster, 7-5 Flagging	Shorter, 7-5 Flagging	Less dead time, 7-5 Flagging	Less headway, 7-5 Flagging
	total user cost	$9,665	$10,397	$13,817	$11,970
	user cost of delays	$6,618	$7,076	$9,043	$8,019
	user cost of decreases	$3,047	$3,321	$4,774	$3,952
	maximum backup (V)	79	81	109	92
	maximum backup length (lane mi)	0.5	0.5	0.6	0.5
You can copy these values into Impact Sheet.	maximum delay (min.)	10.9	11.5	15.2	13.2
	average delay, except diversions (min)	6.0	5.4	7.7	6.4
	total delay, except diversions (V hr)	613	656	838	743
	total vehicles canceled(V)	668	729	1047	867
	total vehicles diverted (V)	891	971	1397	1156
	total decrease in demand (V)	1560	1700	2444	2023
	% decrease in demand	17%	19%	27%	22%
	delay per diverted vehicle (min)	7.3	7.3	7.3	7.3
	total diversion delay (V hr)	109	119	171	141
	average delay, including diversions (min)	6.4	5.6	7.6	6.5
	total delay, including diversions (V hr)	722	775	1009	884
	user cost / design demand	$0.66	$0.71	$0.95	$0.82
	delay cost / actual demand	$0.89	$0.97	$1.38	$1.15
	work zone method travel time (min.)	1.7	1.8	2.4	2.4
	speed delay (min.)	0.7	1.0	1.4	1.4
	maximum capacity (V/hr)	809	787	660	727
	gate delay at maximum capacity (min.)	4.0	4.0	4.0	4.0
	maximum gate and speed delay (min.)	8.7	9.0	9.4	9.4
	maximum backup delay (min.)	2.2	2.5	5.8	3.8
Auto ON Print ON Nov OK	validity of output	VALID	VALID	VALID	VALID

Fig. 4-11 Summary View: Sensitivity to Speed, Length, Dead Time, and Headway

SummaryView - Flagging Operation

Copy This Sheet	period length (min)	60	
	annual traffic growth (%)	3.00%	
Update	years of growth	2	
VEHICLE INPUT		cars	trucks
	design demand (%)	98.0%	2.0%
	user cost per hour ($/V hr)	$10.79	$10.79
	user cost per mile, ($/V mi)	$0.30	$1.00
	user cost per cancellation, ($/V)	$1.20	

PROJECT INFORMATION		REPORT INFORMATION	
PROJECT TITLE	M-43 Overlay Zimmer to Cornell	REPORT TITLE	DETAILED USER COST REPORT SUMMARY VIEW
Paste Values C.S.	33082	DIVISION	
JOB #	36569A	REPORT BY	
START DATE	April, 1995	REPORT DATE	4/1/94
NOTES:			

METHOD INPUT		METHOD 1		METHOD 2		METHOD 3		METHOD 4	
	method title	F, 7A-5P: 6min		F, 7A-5P: 10min		F, 7A-5P: 12min		F, 7A-5P: 15min	
DISTANCE AND SPEED INPUTS	(mi) (mph)	distance	speed	distance	speed	distance	speed	distance	speed
work zone	method travel	1.0	25	1.0	25	1.0	25	1.0	25
	normal travel	1.0	60	1.0	60	1.0	60	1.0	60
diversion	method travel	10.0	45	10.0	45	10.0	45	10.0	45
	normal travel	6.0	60	6.0	60	6.0	60	6.0	60
FLAG OPERATION INPUTS									
	vehicle headway at gate (sec)	3		3		3		3	
	dead time at gate when direction changes (sec)	15		15		15		15	
	allowable gate closed time (min.)	6		10		12		15	
DECREASE TO DEMAND									
	canceled cars (with no delay) (%)								
	canceled trucks (with no delay) (%)								
	canceled cars (with delay) (%/min)	1.5%		1.5%		1.5%		1.5%	
	canceled trucks (with delay) (%/min)								
	diverted cars (with no delay) (%)								
	diverted trucks (with no delay) (%)								
	diverted cars (with delay) (%/min)	2.0%		2.0%		2.0%		2.0%	
	diverted trucks (with delay) (%/min)								
OTHER USER COST INPUT	Update	cars	trucks	cars	trucks	cars	trucks	cars	trucks
	other user cost per actual demand ($/V)	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
	user cost per diversion ($/V)	$2.52	$5.32	$2.52	$5.32	$2.52	$5.32	$2.52	$5.32
	Paste Values	Calculate		Calculate		Calculate		Calculate	

Summary | Go To: Summary | Overall | Traffic | User Cost | Combined | Print: This View | Summary | Overall | All | Setup

PERIOD VALUES (V/period)					(Backup at Start of Flagging) Flag Periods (Capacity at End of Flagging) Demand							
direction:	E	W	Both Directions		(Bsof) Flag	demand	(Bsof) Flag	demand	(Bsof) Flag	demand	(Bsof) Flag	demand
period	historical			design	(Ceof)	actual	(Ceof)	actual	(Ceof)	actual	(Ceof)	actual
12 A	34	22	56	59								
1 A	15	14	29	31								
2 A	17	12	29	31								
3 A	19	8	27	29								
4 A	15	27	42	45								
5 A	32	91	123	130								
6 A	90	265	355	377								
7 A	227	659	886	940	Flag	363	Flag	740	Flag	741	Flag	741
8 A	234	528	762	808	Flag	178	Flag	652	Flag	652	Flag	652
9 A	220	455	675	716	Flag	281	Flag	586	Flag	586	Flag	586
10 A	267	393	660	700	Flag	234	Flag	574	Flag	574	Flag	574
11 A	377	403	780	828	Flag	269	Flag	665	Flag	666	Flag	666
12 P	436	397	833	884	Flag	226	Flag	704	Flag	704	Flag	704
1 P	442	431	873	926	Flag	285	Flag	732	Flag	732	Flag	732
2 P	481	373	854	906	Flag	230	Flag	718	Flag	719	Flag	719
3 P	550	463	1013	1075	Flag	272	Flag	797	Flag	819	Flag	820
4 P	664	479	1143	1213	Flag	297	Flag	807	Flag	881	Flag	888
5 P	749	573	1322	1403	2400		2400		2400		2400	
6 P	534	569	1103	1170								
7 P	395	421	816	866								
8 P	339	179	518	550								
9 P	277	156	433	459								
10 P	165	81	246	261								
11 P	87	42	129	137								
Total	6666	7041	13707	14542		2637		6975		7072		7080

SUMMARY OUTPUT	traffic method	F, 7A-5P: 6min Flagging	F, 7A-5P: 10min Flagging	F, 7A-5P: 12min Flagging	F, 7A-5P: 15min Flagging
	total user cost	$22,042	$12,052	$11,647	$11,611
	user cost of delays	$9,620	$8,105	$7,890	$7,870
	user cost of decreases	$12,422	$3,948	$3,757	$3,741
	maximum backup (V)	129	69	21	0
	maximum backup length (lane mi)	0.7	0.4	0.1	0.0
You can copy these values into Impact Sheet.	maximum delay (min.)	30.9	12.1	12.5	14.2
	average delay, except diversions (min)	16.6	6.5	6.2	6.2
	total delay, except diversions (V hr)	892	751	731	729
	total vehicles canceled(V)	2725	866	824	821
	total vehicles diverted (V)	3633	1155	1099	1094
	total decrease in demand (V)	6358	2021	1923	1915
	% decrease in demand	71%	22%	21%	21%
	delay per diverted vehicle (min)	7.3	7.3	7.3	7.3
	total diversion delay (V hr)	444	141	134	134
	average delay, including diversions (min)	8.3	6.6	6.4	6.3
	total delay, including diversions (V hr)	1336	892	866	863
	user cost / design demand	$1.52	$0.83	$0.80	$0.80
	delay cost / actual demand	$3.65	$1.16	$1.12	$1.11
	work zone method travel time (min.)	2.4	2.4	2.4	2.4
	speed delay (min.)	1.4	1.4	1.4	1.4
	maximum capacity (V/hr)	251	767	860	943
	gate delay at maximum capacity (min.)	3.0	5.0	6.0	7.5
	maximum gate and speed delay (min.)	7.4	11.4	13.4	14.2
	maximum backup delay (min.)	23.5	0.7	-0.9	0.0
Autc ON Print ON Now OK	validity of output	VALID	VALID	VALID	VALID

Fig. 4-12 Summary View: Sensitivity to Allowable Gate Closed Time

traffic method	F, 7A-5P	Faster, 7-5			Shorter, 7-5			Less dead time, 7-5			Less headway, 7-5		
	value	value	difference		value	difference		value	difference		value	difference	
total user cost	$15,478	$9,665	-$5,813	-38%	$10,397	-$5,081	-33%	$13,817	-$1,661	-11%	$11,970	-$3,508	-23%
user cost of delays	$9,886	$6,618	-$3,268	-33%	$7,076	-$2,809	-28%	$9,043	-$843	-9%	$8,019	-$1,867	-19%
user cost of decreases	$5,592	$3,047	-$2,546	-46%	$3,321	-$2,271	-41%	$4,774	-$818	-15%	$3,952	-$1,641	-29%
maximum backup (V)	123	79	-43	-35%	81	-42	-34%	109	-14	-11%	92	-31	-25%
maximum backup length (lane mi)	0.7	0.5	-0.2	-35%	0.5	-0.2	-34%	0.6	-0.1	-11%	0.5	-0.2	-25%
maximum delay (min.)	16.7	10.9	-5.8	-35%	11.5	-5.2	-31%	15.2	-1.6	-9%	13.2	-3.5	-21%
average delay, except diversions (min)	9.0	6.0	-3.0	-33%	5.4	-3.6	-40%	7.7	-1.3	-14%	6.4	-2.6	-29%
total delay, except diversions (V hr)	916	613	-303	-33%	656	-260	-28%	838	-78	-9%	743	-173	-19%
total vehicles canceled(V)	1227	668	-558	-46%	729	-498	-41%	1047	-179	-15%	867	-360	-29%
total vehicles diverted (V)	1636	891	-745	-46%	971	-664	-41%	1397	-239	-15%	1156	-480	-29%
total decrease in demand (V)	2863	1560	-1303	-46%	1700	-1163	-41%	2444	-419	-15%	2023	-840	-29%
% decrease in demand	32%	17%	-14%	-46%	19%	-13%	-41%	27%	-5%	-15%	22%	-9%	-29%
delay per diverted vehicle (min)	7.3	7.3	0.0	0%	7.3	0.0	0%	7.3	0.0	0%	7.3	0.0	0%
total diversion delay (V hr)	200	109	-91	-46%	119	-81	-41%	171	-29	-15%	141	-59	-29%
average delay, including diversions (min)	8.6	6.4	-2.2	-26%	5.6	-3.0	-35%	7.6	-1.0	-12%	6.5	-2.1	-24%
total delay, including diversions (V hr)	1116	722	-394	-35%	775	-342	-31%	1009	-107	-10%	884	-232	-21%
user cost / design demand	$1.06	$0.66	-$0.40	-38%	$0.71	-$0.35	-33%	$0.95	-$0.11	-11%	$0.82	-$0.24	-23%
delay cost / actual demand	$1.61	$0.89	-$0.72	-45%	$0.97	-$0.64	-40%	$1.38	-$0.23	-14%	$1.15	-$0.46	-29%
work zone method travel time (min.)	2.4	1.7	-0.7	-29%	1.8	-0.6	-25%	2.4	0.0	0%	2.4	0.0	0%
speed delay (min.)	1.4	0.7	-0.7	-49%	1.0	-0.3	-25%	1.4	0.0	0%	1.4	0.0	0%
maximum capacity (V/hr)	606	809	204	34%	787	181	30%	660	54	9%	727	121	20%
gate delay at maximum capacity (min.)	4.0	4.0	0.0	0%	4.0	0.0	0%	4.0	0.0	0%	4.0	0.0	0%
maximum gate and speed delay (min.)	9.4	8.7	-0.7	-7%	9.0	-0.3	-4%	9.4	0.0	0%	9.4	0.0	0%
maximum backup delay (min.)	7.3	2.2	-5.2	-70%	2.5	-4.8	-66%	5.8	-1.6	-21%	3.8	-3.5	-48%

Fig. 4-13 Sensitivity to Speed, Length, Dead Time, and Headway

traffic method	F, 7A-5P	F, 7A-5P: 6min			F, 7A-5P: 10min			F, 7A-5P: 12min			F, 7A-5P: 15min		
	value	value	difference		value	difference		value	difference		value	difference	
total user cost	$15,478	$22,042	$6,564	42%	$12,052	-$3,426	-22%	$11,647	-$3,831	-25%	$11,611	-$3,867	-25%
user cost of delays	$9,886	$9,620	-$265	-3%	$8,105	-$1,781	-18%	$7,890	-$1,996	-20%	$7,870	-$2,016	-20%
user cost of decreases	$5,592	$12,422	$6,829	122%	$3,948	-$1,645	-29%	$3,757	-$1,835	-33%	$3,741	-$1,851	-33%
maximum backup (V)	123	129	7	5%	69	-54	-44%	21	-102	-83%	0	-123	-100%
maximum backup length (lane mi)	0.7	0.7	0.0	5%	0.4	-0.3	-44%	0.1	-0.6	-83%	0.0	-0.7	-100%
maximum delay (min.)	16.7	30.9	14.2	85%	12.1	-4.7	-28%	12.5	-4.3	-25%	14.2	-2.5	-15%
average delay, except diversions (min)	9.0	16.6	7.6	85%	6.5	-2.5	-28%	6.2	-2.8	-31%	6.2	-2.8	-31%
total delay, except diversions (V hr)	916	892	-25	-3%	751	-165	-18%	731	-185	-20%	729	-187	-20%
total vehicles canceled(V)	1227	2725	1498	122%	866	-361	-29%	824	-403	-33%	821	-406	-33%
total vehicles diverted (V)	1636	3633	1998	122%	1155	-481	-29%	1099	-537	-33%	1094	-541	-33%
total decrease in demand (V)	2863	6358	3496	122%	2021	-842	-29%	1923	-939	-33%	1915	-948	-33%
% decrease in demand	32%	71%	39%	122%	22%	-9%	-29%	21%	-10%	-33%	21%	-11%	-33%
delay per diverted vehicle (min)	7.3	7.3	0.0	0%	7.3	0.0	0%	7.3	0.0	0%	7.3	0.0	0%
total diversion delay (V hr)	200	444	244	122%	141	-59	-29%	134	-66	-33%	134	-66	-33%
average delay, including diversions (min)	8.6	8.3	-0.4	-4%	6.6	-2.0	-24%	6.4	-2.3	-26%	6.3	-2.3	-27%
total delay, including diversions (V hr)	1116	1336	220	20%	892	-224	-20%	866	-251	-22%	863	-253	-23%
user cost / design demand	$1.06	$1.52	$0.45	42%	$0.83	-$0.24	-22%	$0.80	-$0.26	-25%	$0.80	-$0.27	-25%
delay cost / actual demand	$1.61	$3.65	$2.04	126%	$1.16	-$0.45	-28%	$1.12	-$0.50	-31%	$1.11	-$0.50	-31%
work zone method travel time (min.)	2.4	2.4	0.0	0%	2.4	0.0	0%	2.4	0.0	0%	2.4	0.0	0%
speed delay (min.)	1.4	1.4	0.0	0%	1.4	0.0	0%	1.4	0.0	0%	1.4	0.0	0%
maximum capacity (V/hr)	606	251	-355	-59%	767	162	27%	860	254	42%	943	337	56%
gate delay at maximum capacity (min.)	4.0	3.0	-1.0	-25%	5.0	1.0	25%	6.0	2.0	50%	7.5	3.5	88%
maximum gate and speed delay (min.)	9.4	7.4	-2.0	-21%	11.4	2.0	21%	13.4	4.0	43%	14.2	4.8	51%
maximum backup delay (min.)	7.3	23.5	16.2	221%	0.7	-6.7	-91%	-0.9	-8.3	-113%	0.0	-7.3	-100%

Fig. 4-14 Sensitivity to Allowable Gate Closed Time

4.4.2 GUIDELINES FOR FLAGGING OPERATIONS

- Flagging is a typical method of maintaining traffic during construction or maintenance on one lane of a two lane road, because it is the most convenient way to close a lane and maintain traffic in both directions. Its seemingly straightforward nature masks a complex operation that can cause major traffic congestion and construction problems. $MCon^2Flag$ provides a tool that can help project planners to understand and apply engineering judgment to flagging operations and select methods whose impacts are acceptable.

- Traffic and user cost impacts are quite sensitive to flagging variables, as demonstrated by the relationships, examples, and sensitivity analysis in this chapter. Good planning and management can yield major benefits.
- Work zone length should be kept to a minimum. We close only the length that is required for current work, because congestion is so sensitive to work zone length. If work location moves from hour to hour, we generally must move the zone with it, except if traffic is light. We use MCon2Flag to help us select an acceptable length, when there are trade-off between construction impact and traffic impact.
- Work zone speed should be maintained as high as possible, considering worker and traffic safety. Platoon traffic will generally set its own speed, given the road conditions in the work zone. Good signing, clean and clear surfaces, and clearance from construction work can help maintain an acceptable speed.
- Dead time at gates has multiple causes that generally can be controlled, and we use $MCon^2Flag$ to help us select acceptable levels. Tasks that require both lanes to be closed for short periods, such as for an excavator to load a truck, should be minimized, if not prohibited. If they cannot be prevented, they should be done only during light traffic. Long dead time is often caused flaggers making sure the zone is clear of oncoming vehicles before they open their gate. Good communication between flaggers can prevent such problems. Dead time can also be shortened by good communication between a flagger and the lead vehicle waiting for the gate to open.
- Headway at flagging gates, just as at signal lights, is a function of driver understanding, vision, speed, and road conditions. An obvious gate entrance, good vision, ample advance notice of when the gate will open, and good zone travel speed will encourage low headway, which significantly increases capacity and reduces congestion.
- Flaggers should be selected with care and trained in traffic management and control. They should be provided with a method with which to communicate, so each knows what conditions are at the other gate. Each flagger can identify the last vehicle in the platoon entering its gate, for example, so the other flagger knows when the last vehicle has exited its gate. Intermediate spotters can help flaggers control traffic in long work zone.
- A specific traffic management strategy should be designed for each project, in the manner described in this section. Actual performance should be measured often enough to determine if the strategy is being followed, is working, or should be altered to fit actual conditions encountered.
- A single vehicle can block all traffic if the vehicle is in the one lane of the work zone or in the open lane beside the queue at either end. Traffic management must include a method to quickly move vehicles that stall and block traffic.
- Traffic control must guard against vehicles traveling against grain of oncoming platoon, such as vehicles entering zone from side roads or driveways and going in direction opposite that of the next platoon. Similarly, traffic control must guard against vehicles passing others in the queue. There is no place for a passer to return to its lane, and it blocks the lane to oncoming traffic that must clear the zone.

CONSTRUCTION CONGESTON COST

CO^3 USER MANUAL

CHAPTER 5

TRAFFIC DEMAND AND DELAY MODEL

5.1 INTRODUCTION

Speeds within work zones are also classified by normal travel speed and method travel speed:

- **work zone normal travel speed** = average speed vehicles will travel if there is no work zone.
- **diversion method travel speed** = average speed vehicles that divert will travel on the diversion route.
- **diversion normal travel speed** = average speed vehicles travel over the diversion normal travel distance, when there is no work zone.
- **work zone method travel speed** = speed vehicles travel through the work zone during construction, based on conditions that vary with demand and capacity in the work zone. This is calculated by CO^3 based on input described below.

The basic model calculates **user cost** caused by disruption of regular traffic due to highway work, based on two variables that describe the disruption, **demand decrease = decrease in design demand** and **delay.** Calculation is a three stage process:

1. Calculate **design demand**, which is the estimated traffic demand with no disruption.
2. Calculate **delay, demand decrease, actual demand**, and related variables, including **backup (B)**.
3. Calculate **user cost** due to demand decrease and delay.

5.2 DESIGN DEMAND

Design demand can be estimated directly, but it normally will be directly calculated from **historical demand,** with adjustment for **years of growth** between the year in which historical demand is determined and the year in which the work will be performed, based on estimated **annual traffic growth**:

$$\text{design demand} = (\text{historical demand}) * \left[1 + (\text{annual traffic growth})\right]^{(\text{years of growth})} \qquad (85)$$

5.3 SPEED DELAY

5.3.1 GENERAL

Vehicle speed through a construction zone may be lower than speeds outside the zone, due to pavement conditions, traffic conditions, routing through a detour, or other work zone conditions. If a detour is used, it may also add distance to the travel, which would increase travel distance and time. Traffic control, such as one way travel through the zone or other use of flaggers or signals that produces stop-and-go traffic, can also increase travel time. These increases in time required to traverse the zone over a primary route is called the vehicle **speed delay**, and this section describes input variables and calculation of speed delay.

5.3.2 SPEED DELAY = FUNCTION OF DEMAND AND CAPACITY

The model allows **speed delay** of a vehicle to vary as work zone conditions and traffic conditions change. Work zone conditions change from time to time as lanes or ramps are closed and opened or as traffic is routed over temporary paving or detours. Therefore, work zone conditions change when **capacity** changes. Traffic conditions change as work zone conditions change and as demand changes. Speed delay is modeled as a function of capacity and demand, as shown in Fig. 5-1. That is, for each capacity that has a speed delay function, the value of its speed delay is a function of the ratio of demand to capacity, or ***D/C***, as *D/C* varies from 0 to 1. Speed delay never exceeds its value at *D/C* = 1, because traffic flow through the zone cannot exceed capacity, by definition, and all demand greater than capacity backs up and waits to enter the zone.

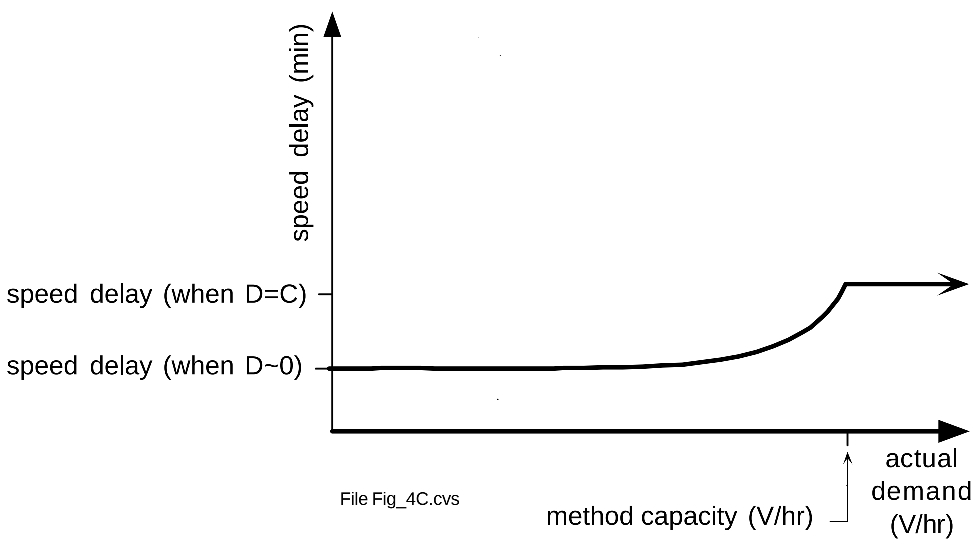


Fig. 5-1 Speed Delay as Function of Demand / Capacity

For example, for a work zone 1 mile long, consider closing one lane of a four lane highway, which we estimate reduces capacity from capacity = 6400 to capacity = 5000 VPH. Let us assume that at capacity = 5000 VPH we estimate average vehicle speed at low traffic will be reduced from normal speed = 70 MPH to [method speed (when *D*»0)] = 55 MPH due to construction conditions. When traffic through the zone equals the zone capacity, we estimate average vehicle speed will slow to [method speed (when *D*=*C*)] = 40 MPH. The time required to traverse the distance at normal speed can be calculated from the following:

$$\text{normal time} = \frac{\text{work zone normal distance}}{\text{work zone normal speed}}$$
$$= \frac{1 \text{ mile}}{70 \text{ miles / hr}} = 0.01428 \text{ hr} = 0.86 \text{ min.} \tag{86}$$

Method time at low traffic and high traffic are calculated from:

$$\text{method time (when } D \approx 0) = \frac{\text{work zone method distance}}{\text{work zone method speed (when } D \approx 0)}$$
$$= \frac{1 \text{ mile}}{55 \text{ miles / hr}} = 0.01818 \text{ hr} = 1.09 \text{ min.} \tag{87}$$

$$\text{method time (when } D = C) = \frac{\text{work zone method distance}}{\text{work zone method speed (when } D = C)}$$
$$= \frac{1 \text{ mile}}{40 \text{ miles / hr}} = 0.02500 \text{ hr} = 1.50 \text{ min.} \tag{88}$$

Speed delay at low traffic and high traffic are calculated from:

$$\text{speed delay (when } D \approx 0) = [\text{method time (when } D \approx 0)] - [\text{normal time}]$$
$$= 1.09 - 0.86 = 0.23 \text{ min} \tag{89}$$

$$\text{speed delay (when } D = C) = [\text{method time (when } D = C)] - [\text{normal time}]$$
$$= 1.50 - 0.86 = 0.64 \text{ min} \tag{90}$$

We also estimate that closing two lanes will reduce capacity to C = 3400 VPH, at which method speed (when D»0) = 55 MPH and method speed (when D=C) = 30 MPH. For these values, we calculate method time (when D≈0) = 1.09 min and speed delay (when D≈0) = 0.23 min (as when C = 5000 VPH) and method time (when D=C) = 2.00 min and speed delay (when D=C) = 1.14 min.

5.3.3 0 < DEMAND < CAPACITY

The general equation for speed delay as a function of D and C is

$$\text{speed delay} = [\text{speed delay (when } D \approx 0)] + \left\{ \begin{array}{l} [\text{speed delay (when } D = C)] \\ -[\text{speed delay (when } D \approx 0)] \end{array} \right\} * \left(\frac{D}{C}\right)^{E_S} \quad \text{for } D < C \tag{91}$$
$$= [\text{speed delay (when } D = C)] \quad \text{for } D \geq C$$

where E_S = speed delay exponent (default value: E_S = 2). Fig. 5-1 illustrates Eq. (91).

Speed delay at an intermediate demand between zero and capacity, such as at D = 3000 VPH at which D/C = 3000/5000 = 0.6, is calculated using Eq. (91),

$$\text{speed delay (when } D = 3000) = 0.23 + (0.64 - 0.23)\left(\frac{3000}{5000}\right)^2$$
$$= 0.23 + (0.41)(0.6)^2 = 0.17 + (0.41)(0.36)$$
$$= 0.23 + 0.15 = 0.38 \text{ min}$$

5.3.4 THRESHOLD CAPACITY

If (1) capacity is the same for all periods during construction or (2) if all capacities during construction have the same speed delay values, then we input only threshold values into CO^3, as shown in Fig. 5-2 from the Input Sheet.[10] This shows (threshold capacity for speed delay) = 5000 V/hr, [speed (when *D*≈0)] = 55 mph, and [speed (when *D*=*C*)] = 40 mph, as in the example above. Fig. 5-2 also shows calculated values of travel time and speed delay. The speed delay function for all capacity ≤ threshold capacity is shown in Fig. 5-4 (a). Speed delay = 0 for all capacity > threshold capacity, including normal capacity.

	DISTANCE AND SPEED INPUT	distance	speed
1	work zone method travel	1.0	see delay
1	work zone normal travel	1.0	70
1	diversion method travel	12.0	50
1	diversion normal travel	10.0	65
	SPEED DELAY INPUT	**threshold**	**range**
2	capacity for speed delay (V/hr)	5000	
3	speed (when D~0) (mph)	55	
3	speed (when D=C) (mph)	40	
	WORK ZONE TRAVEL	**threshold**	**range**
	method travel time (when D~0) (min)	1.09	
	normal travel time (min)	0.86	
	speed delay (when D~0) (min)	0.23	
	method travel time (when D=C) (min)	1.50	
	speed delay (when D=C) (min)	0.64	

Fig. 5-2 Threshold Speed Delay Values

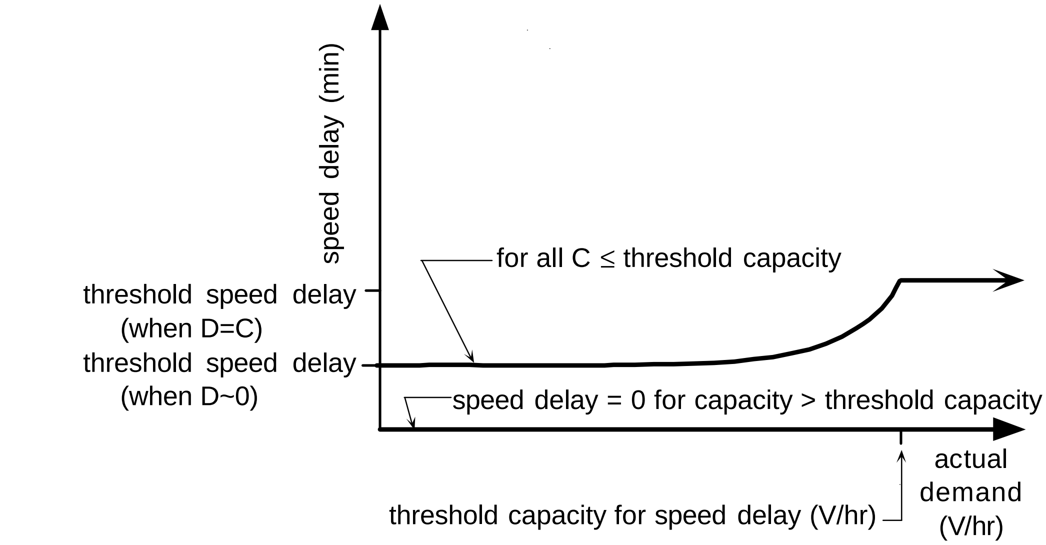
[10] Diversion input is shown in light gray in Fig. 5-1, because it is not pertinent to calculation of speed delay values.

5.3.5 THRESHOLD AND RANGE CAPACITY

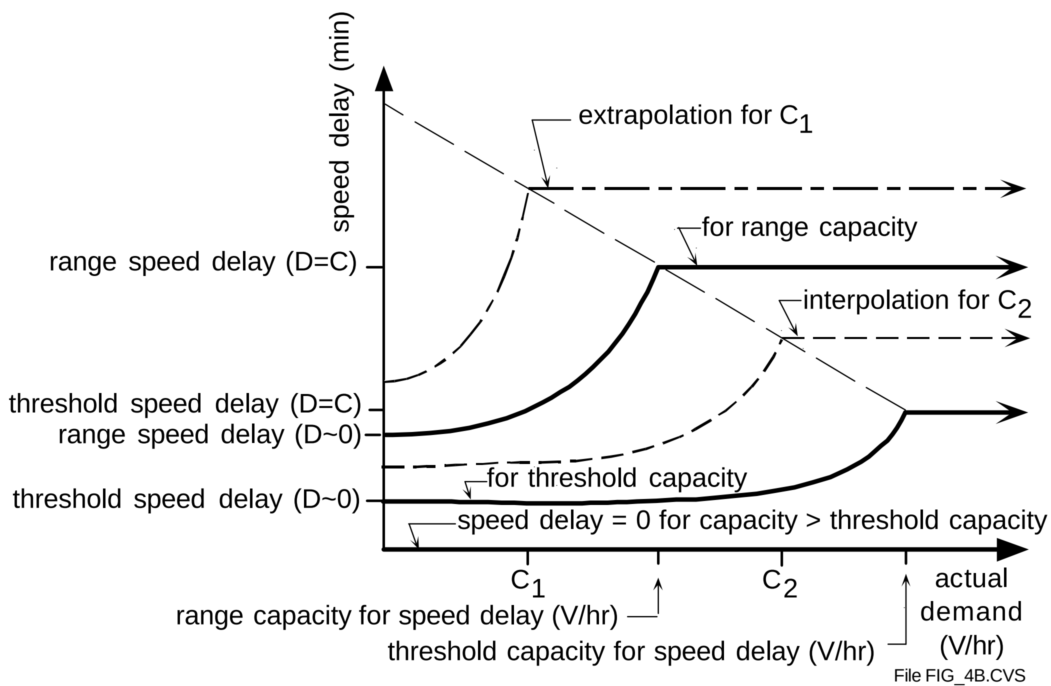
If there is more than one method capacity and if the speed delay function values differ with capacity, then we input both threshold values and range values, as shown in Fig. 5-3. This shows (range capacity for speed delay) = 3400 V/hr, [speed (when $D \approx 0$)] = 55 mph, and [speed (when $D = C$)] = 30 mph, as in the example in Sec. 5.3.2. Fig. 5-3 also shows calculated values of travel time and speed delay for both threshold and range input. Speed delay functions for capacity ≤ threshold capacity are shown in Fig. 5-4 (b). Speed delay = 0 for capacity > threshold capacity, including normal capacity.

DISTANCE AND SPEED INPUT		distance	speed
1	work zone method travel	1.0	see delay
1	work zone normal travel	1.0	70
1	diversion method travel	12.0	50
1	diversion normal travel	10.0	65
SPEED DELAY INPUT		**threshold**	**range**
2	capacity for speed delay (V/hr)	5000	3,400
3	speed (when D~0) (mph)	55	55
3	speed (when D=C) (mph)	40	30
WORK ZONE TRAVEL		**threshold**	**range**
	method travel time (when D~0) (min)	1.09	1.09
	normal travel time (min)	0.86	0.86
	speed delay (when D~0) (min)	0.23	0.23
	method travel time (when D=C) (min)	1.50	2.00
	speed delay (when D=C) (min)	0.64	1.14

Fig. 5-3 Threshold and Range Speed Delay Values



(a) With threshold capacity for speed delay



(b) With threshold and range capacities for speed delay

Fig. 5-4 Speed Delay as Function of Capacity and Demand

5.3.6 CAPACITY ¹ THRESHOLD CAPACITY OR RANGE CAPACITY

When there is range input as well as threshold input, CO^3 calculates values of any variable x_C = value of x at capacity = C < threshold capacity by the following interpolation:

$$x_C = (\text{threshold } x) + \left[(\text{range } x) - (\text{threshold } x)\right] * \left[\frac{(\text{threshold capacity}) - C}{(\text{threshold capacity}) - (\text{range capacity})}\right] \quad (92)$$

where (threshold x) = value of x at threshold capacity and (range x) = value of x at range capacity.

The dashed lines in Fig. 5-4 (b) show interpolated values for capacity C_2, where (threshold capacity) > C_2 > (range capacity) and extrapolated values for capacity C_1< (range capacity). Thus we can model one open lane with estimated capacity = 1400 Vph for the example above, as well as two lanes and three lanes. For this, we input threshold capacity = 5000 VPH and range capacity = 3400 VPH. From these, CO^3 can calculate speed delay for any other capacity

For capacity = 1400 Vph, Eq. (92) calculates

$$\text{method time (when } D \approx 0) = (1.09) + \left[(1.09) - (1.09)\right] * \left[\frac{5000-1400}{5000-3400}\right] = 1.09\,\text{min}$$

$$\text{method time (when } D = C) = 1.50 + \left[(2.00) - (1.50)\right] * \left[\frac{5000-1400}{5000-3400}\right]$$
$$= 1.50 + \left[0.50\right] * \left[2.25\right] = 1.50 + 1.12 = 2.62\,\text{min}$$

which is one mile travel time at average speed = 22.9 mph. Similarly, CO^3 calculates speed delay (when D=C) for capacity = 1400 Vph,

$$\text{speed delay (when } D = C) = 0.64 + \left[(1.14) - (0.64)\right] * \left[\frac{5000-1400}{5000-3400}\right]$$
$$= 0.64 + \left[0.50\right] * \left[2.25\right] = 0.64 + 1.12 = 1.76\,\text{min}$$

which agrees with Eq. (90), from which [speed delay (when D=C)] = 2.62 – 0.86 = 1.76 min.

5.4 DECREASES TO DESIGN DEMAND

5.4.1 DEMAND DECREASE = FUNCTION OF DELAY

Actual demand (Vph) is **design demand** minus decrease to design demand due to delay, which we call **demand decrease**. Demand decrease is handled in a manner that is similar to speed delay. CO^3 allows two types of decreases: cancellations and diversions and two vehicle streams: cars and trucks, for a total of four combinations. Generally, historical demand = demand from traffic counts = normal demand, and there is no demand decrease under normal traffic conditions. However, speed delay and backup delay during construction are generally expected to cause decreases as some user divert their travel from the work zone and others cancel trips they would normally have made.

The general equation for demand decrease is the following:

$$\text{demand decrease (V / hr)} = \left[\text{decrease (\%)}\right] * \left[\text{design demand (V / hr)}\right] \qquad (93)$$

where **decrease %** = the per cent of design demand that diverts or cancels their trips. Decrease % is a function of users' knowledge of conditions (including diversion routes), users' access to diversion routes, and delays encountered by users. CO^3 models decrease % by,

$$\text{decrease \%} = \left[\text{decrease (with no delay) (\%)}\right] + \left[\text{decrease (with delay) (\% / min)}\right] * \left[\text{delay (min)}\right] \qquad (94)$$

which is demonstrated in Fig. 5-5 for diverted cars. Actual demand is described by

$$\text{actual demand (V / hr)} = [\text{design demand (V / hr)}] - [\text{demand decrease (V / hr)}] = [\text{design demand (V / hr)}] * \{1 - [\text{decrease (\%)}]\} \quad (95)$$

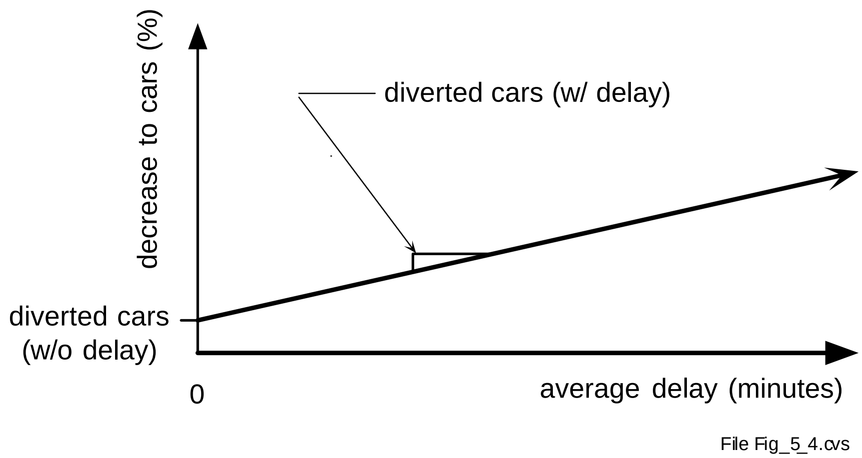


Fig. 5-5 Percent Decrease in Car Demand as Function of Delay

5.4.2 THRESHOLD CAPACITY

If (1) capacity is the same for all periods during construction or (2) if all capacities during construction have the same demand decrease values, then we input only threshold values for demand decreases, as shown in Fig. 5-6, which shows threshold capacity for decreases to design demand = 5000 Vph. Fig. 5-8 (a) shows the relationship between diverted cars and delay for the threshold capacity. To demonstrate the CO^3 model, we input the diverted car values from Fig. 5-7 into Eq. (94), to calculate diverted cars when demand = 3000 Vph = 0.6 * (capacity = 5000 Vph) speed delay = 0.38 min. By Eq. (94),

$$\text{diverted cars} = [\text{decrease (with no delay)} = 3\%] + [\text{decrease (with delay)} = 1\% / \text{min}] * [\text{delay} = 0.38 \text{ min}] = 3\% + 0.38\% = 3.38\%$$

5.4.3 THRESHOLD AND RANGE CAPACITY

If there is more than one method capacity and if demand decrease values differ with capacity, then we input both threshold values and range values, as shown in Fig. 5-7, which shows (range capacity for decreases to design demand) = 3400 Vph. The demand decrease functions for capacity ≤ threshold capacity is shown in Fig. 5-8 (b). Demand decrease = 0 for capacity > threshold capacity, including normal capacity. We can demonstrate CO^3 calculations for demand > range capacity = 3400 Vph, average backup delay = 5 min. From the example in Sec. 5.3.2 for capacity = 3400 Vph, [speed delay (when D=C)] = 1.14 min, so average delay = 5 + 1.14 = 6.14 min. By Eq. (94),

$$\text{diverted cars} \;=\; \left[\text{decrease (with no delay)} = 5\%\right]$$
$$+\left[\text{decrease (with delay)} = 1\% / \text{min}\right] * \left[\text{delay} = 6.14 \text{ min}\right]$$
$$= 5\% + 6.14\% = 11.14\%$$

DECREASE TO DEMAND		threshold	range
2	capacity for decreases to design demand (V/hr)	5000	
6	canceled cars (with no delay) (%)	2.0%	
6	canceled trucks (with no delay) (%)		
6	canceled cars (with delay) (%/min)	1.0%	
6	canceled trucks (with delay) (%/min)		
5	diverted cars (with no delay) (%)	3.0%	
5	diverted trucks (with no delay) (%)		
5	diverted cars (with delay) (%/min)	1.0%	
5	diverted trucks (with delay) (%/min)	0.5%	

Fig. 5-6 Threshold Input for Decrease to Demand

DECREASE TO DEMAND		threshold	range
2	capacity for decreases to design demand (V/hr)	5000	3400
6	canceled cars (with no delay) (%)	2.0%	4.0%
6	canceled trucks (with no delay) (%)		
6	canceled cars (with delay) (%/min)	1.0%	1.0%
6	canceled trucks (with delay) (%/min)		
5	diverted cars (with no delay) (%)	3.0%	5.0%
5	diverted trucks (with no delay) (%)		
5	diverted cars (with delay) (%/min)	1.0%	1.0%
5	diverted trucks (with delay) (%/min)	0.5%	0.5%

Fig. 5-7 Threshold and Range Input for Decrease to Demand

5.4.4 CAPACITY ¹ THRESHOLD CAPACITY OR RANGE CAPACITY

When there is range input as well as threshold input, CO^3 models decreases to design demand for capacity < threshold capacity by interpolation for capacity between threshold capacity and range capacity and extrapolation for all capacity < range capacity, in accordance with the Eq. (92). For example, we can calculate the decrease to design demand for one lane open, for demand > capacity = 1400 Vph.

$$\text{diverted cars (with no delay)} = 3\% + \left[(5\%/\text{min}) - (3\%/\text{min})\right] * \left[\frac{5000-1400}{5000-3400}\right]$$

$$= 3\% + \left[2\%/\text{min}\right] * \left[2.25\right] = 3\% + 4.5\% = 7.5\%$$

$$\text{diverted cars (with delay)} = 1\% + \left[(1\%/\text{min}) - (1\%/\text{min})\right] * \left[\frac{5000-1400}{5000-3400}\right]$$

$$= 1\% + \left[0\%/\text{min}\right] * \left[2.25\right] = 1\%$$

From the example in Sec. 5.3.6, pg. 5-6 for capacity = 1400 Vph, [speed delay (when D=C)] = 1.76 min. If average backup delay = 10 min, then average delay = 10 + 1.76 = 11.76 min. By Eq. (94),

$$\text{diverted cars} = \left[\text{decrease (with no delay)} = 7.5\%\right]$$

$$+ \left[\text{decrease (with delay)} = 1\%/\text{min}\right] * \left[\text{delay} = 11.76\ \text{min}\right]$$

$$= 7.5\% + 11.76\% = 19.26\%$$

5.5 BACKUP DELAY

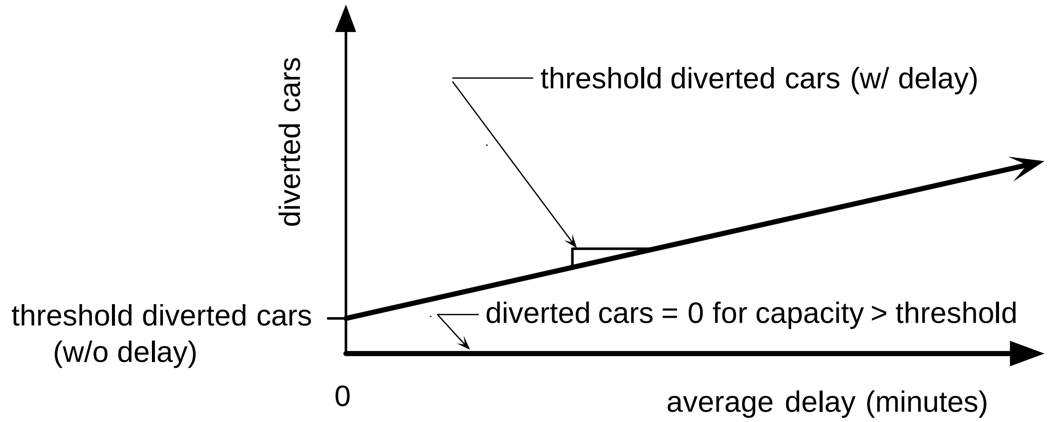
A backup is a queue of vehicles that is waiting to enter a work zone, and backup delay is the time a vehicle waits in the queue to enter the zone. CO^3 assumes arrivals and departures are uniformly distributed over each period. Backup is the excess of demand over capacity, and all vehicles ahead of a particular vehicle must pass through the zone before it can. Therefore, a vehicle that arrives when there is a backup must wait to enter the zone until the backup ahead of it has entered the zone. If there are B_N vehicles backed-up when vehicle N arrives, and the capacity (V/period) of the zone is capacity_N following the arrival of N, vehicle N is delayed by $(\text{backup delay})_{B_N}$ while it waits to enter the zone, where

$$\left[\text{backup delay (min)}\right]_{B_N} = \frac{\left[B_N(\text{V})\right]\left[60(\text{min/hr})\right]}{\left[\text{capacity}_N(\text{V/hr})\right]} \tag{96}$$

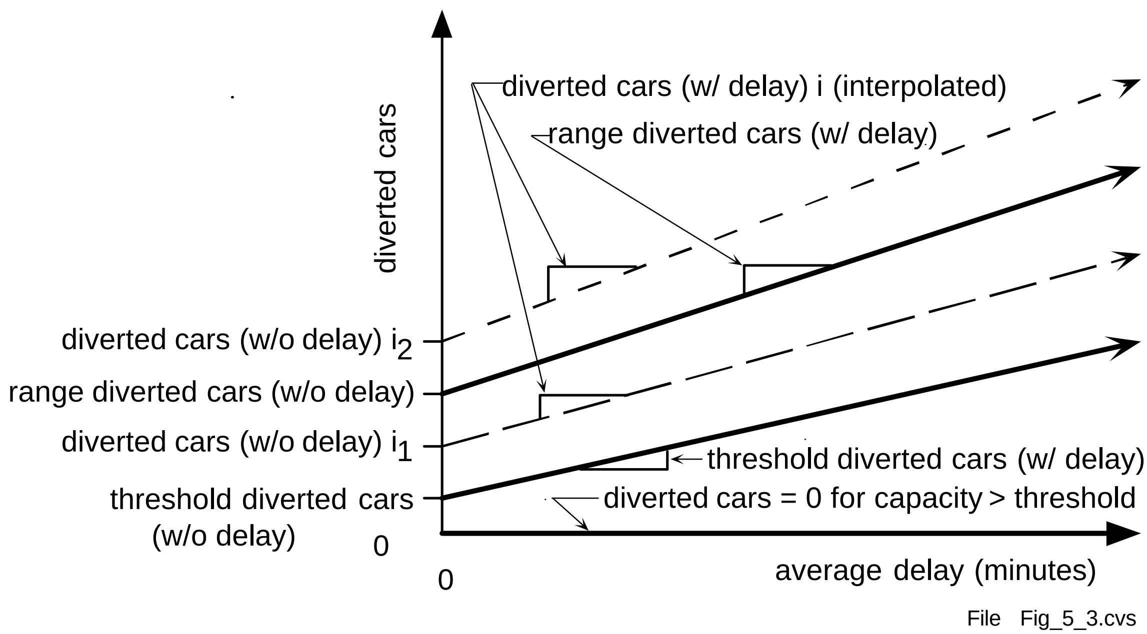
These relationships are shown in Fig. 5-9, in which $B_{sop\ i}$ = backup at start of period i, and $B_{eop\ i}$ = backup at end of period i. Vehicles arriving at the start of period 1 are behind backup $B_{sop\ 1}$. The last vehicle in that backup enters the zone at time a, after which time the first vehicles arriving in period 1 will start entering the zone. The number of period 1 vehicles that enter the zone during period 1 = e – d . If period 1 demand = $\text{demand}_{1,1}$, then the end of period backup = $B_{eop\ 1,1}$ is the start of period 2 backup = $B_{sop\ 2,1}$, and the last arriving period 1 vehicle will be backed-up until time b, at which time all of $\text{demand}_{1,1}$ will have entered the zone. Thus, all period 1 vehicles will have entered the zone before the end of period 2, and the end of period 2 backup = $B_{eop\ 1,1}$ = 0. The total vehicle-periods period 1 vehicles will have spent in backups is the cross-hatched area = $(\text{total backup delay})_{1,1}$.

However, if period 1 demand = $\text{demand}_{1,2}$, then period 1 vehicles will remain into period 3, the latest arriving period 1 vehicles will be backed-up from the end of period 1 until c, and the total vehicle-periods of backup delay accumulated by period 1 vehicles will be the area = $(\text{total backup delay})_{1,2}$.

Thus, the total vehicle-periods of delay due to backups experienced by vehicles that arrive in a period is a function of the backup at the start of the period, the period demand, and the period capacity. It is also a function of the following periods' capacities, if the initial start of period backup and period demand exceed the period capacity.



(a) With threshold capacity for decreases



(b) With threshold and range capacities for decreases

Fig. 5-8 Percent Decrease in Car Demand for Threshold and Range Values

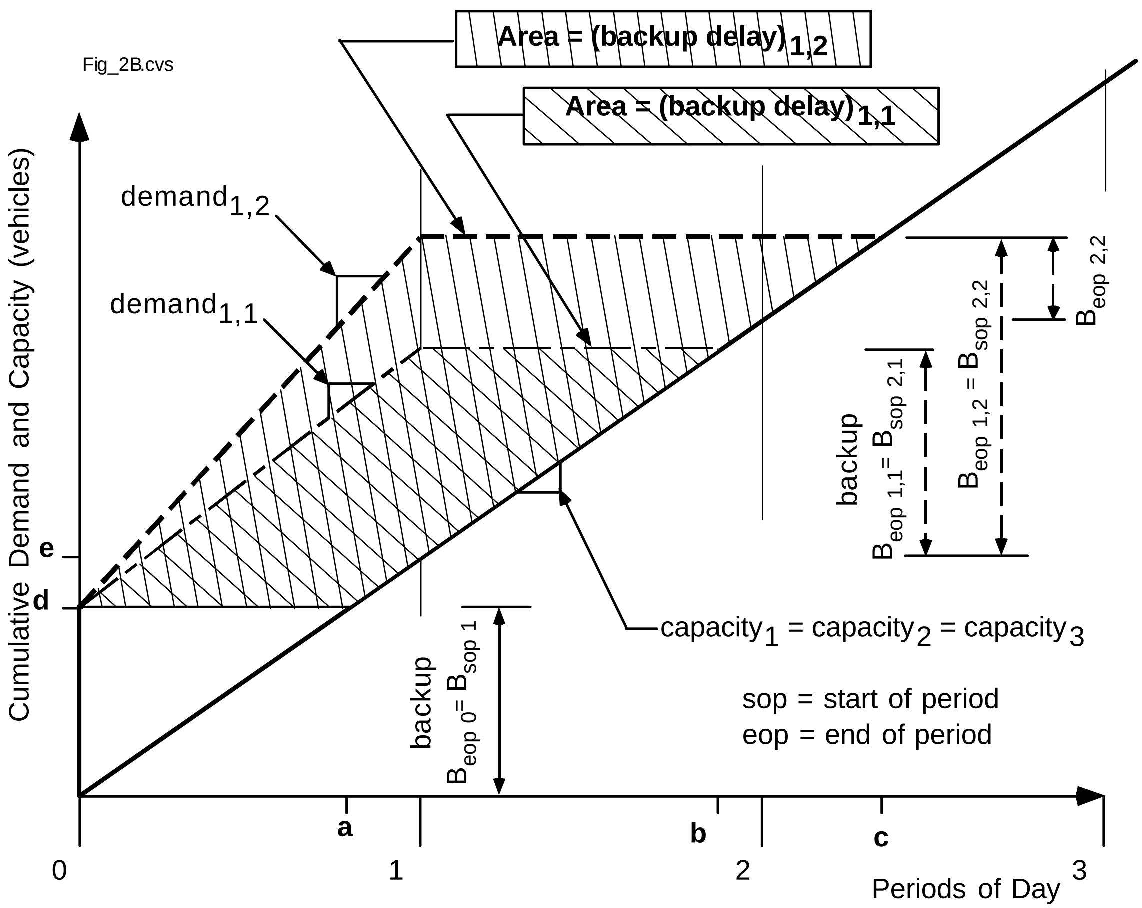


Fig. 5-9 Comparison of Backup Delay for Two Demands

5.6 DELAY, DEMAND DECREASE, AND ACTUAL DEMAND

Demand decrease, actual demand, and **delay** cannot be calculated directly, because demand decrease is dependent on average delay per vehicle, and average delay per vehicle is dependent on actual demand, which is dependent on demand decrease. Because of this dependency loop, CO^3 uses an iterative method to calculate these variables for each period. The basic process used by the CO^3 is the following, which is diagrammed in Fig. 5-10.

1. Based on input information, estimate trial value for period *i*:
   - trial actual demand = demand_{trial}
2. Based on trial actual demand, calculate trial values of delay per vehicle due to backup and delay due to speed for *i*:
   - trial total backup delay = $(\text{total backup delay})_{trial}$

- trial average backup delay per vehicle = $(\text{backup delay})_{trial}$ =
= $(\text{total backup delay})_{trial}$ / demand_{trial}

- trial average speed delay per vehicle = $(\text{speed delay})_{trial}$

3. Based on trial values of backup delay and speed delay, calculate a trial estimated average delay per vehicle = delay_{trial} = $(\text{backup delay})_{trial}$ + $(\text{speed delay})_{trial}$
4. Based on the trial estimated average delay per vehicle, calculate a new percent decrease in demand = decrease_{new}. This can be calculated for a single vehicle class or separately for cars and trucks.
5. Based on the new percent decrease in demand, calculate a new estimated actual demand = demand_{new}.
6. Based on new actual demand, calculate new values of delay per vehicle due to backup and delay due to speed for *i*:

- new total backup delay = $(\text{total backup delay})_{new}$

- new average backup delay per vehicle = $(\text{backup delay})_{new}$ =
= $(\text{total backup delay})_{new}$ / demand_{new}

- new average speed delay per vehicle = $(\text{speed delay})_{new}$

7. Based on trial values of backup delay and speed delay, calculate a new estimated average delay per vehicle = delay_{new} = $(\text{backup delay})_{new}$ + $(\text{speed delay})_{new}$
8. Determine whether the new estimates of demand or delay are significantly different from the trial estimates. That is, is demand_{new} significantly different from demand_{trial} or is delay_{new} significantly different from delay_{trial}?

- If either new estimate is significantly different, calculate a new trial value of demand = demand_{trial} based on the past value of demand_{trial} and demand_{new}, and repeat steps 1-8 above for the new demand_{trial}.

- If neither new estimate is significantly different, then set the values of actual demand, average delay, and other demand and delay variables for period *i* to the new estimated values, and perform steps 1-8 above for time period (*i* + 1) = period following *i*.

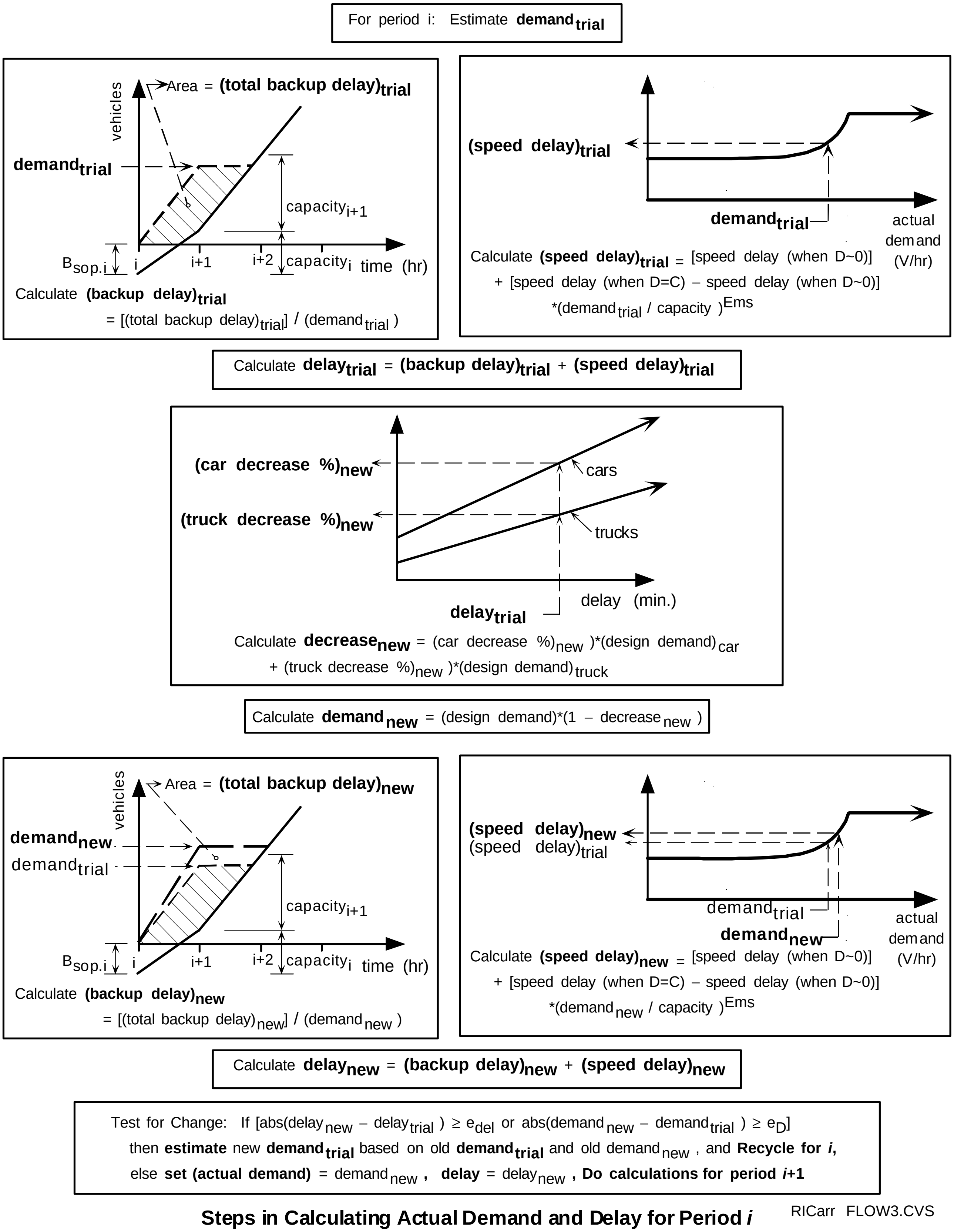


Fig. 5-10 Steps in Calculating Actual Demand and Delay for Period *i*.

CO3 CONSTRUCTION CONGESTON COST

CO^3 USER MANUAL

APPENDIX 1

INDEX*

* **Bold** = primary definition or description. ***Bold-italic*** = equation.

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