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Volume I: Final Report

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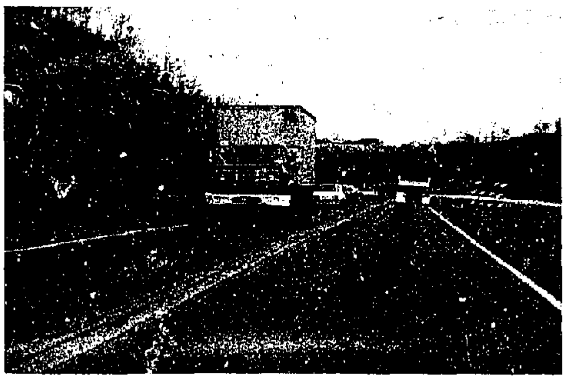

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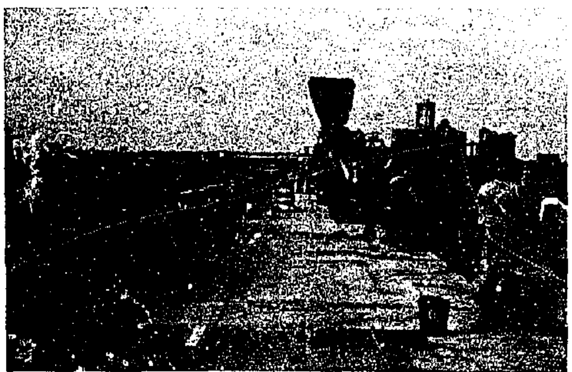

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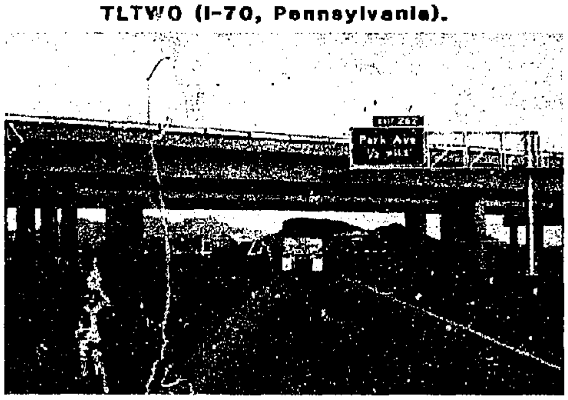

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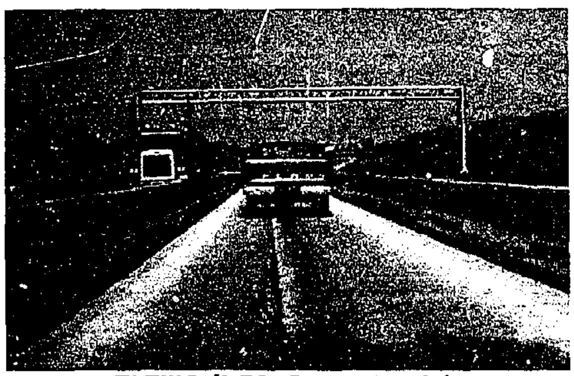

TLTWO (I-78, Pennsylvania).

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16. Abstract

Research was performed to determine total costs (construction and road user costs) and safety impacts associated with traffic control through work zones on rural four-lane, divided highways using single lane closure (SLC) versus two-lane, two-way traffic operations (TLTWO). An informational guide for use in selecting cost-effective traffic control strategies for proposed construction projects was also prepared.

Construction data were collected from 51 construction projects in 11 States, and traffic capacity delay studies were conducted at 25 projects in 10 States. In all, construction projects were studied in 16 different states.

A total of seven types of construction projects were analyzed for the two traffic control alternatives. The type of construction was found to be the most important aspect affecting the selection of the most cost-effective traffic control strategy. The average daily traffic for the projects ranged from approximately 10,000 to 30,000. For the projects studied, there were no significant differences in accident rates between the two traffic control alternatives Guidelines are presented for selection of SLC versus TLTWO, including a simplified procedure to estimate road user costs for SLC and TLTWO traffic control strategies.

This final report is the first volume of this two-volume series. The second volume is the informational guide (Publication No. FHWA-RD-89-210.)

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APPROXIMATE CONVERSIONS TO SI UNITS

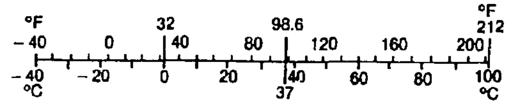
Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.093	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometres squared	km^2
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.028	metres cubed	m^3
yd^3	cubic yards	0.765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
	MASS			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5(F-32)/9	Celcius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometres squared	0.386	square miles	mi^2
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3
	MASS			
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
	TEMPERATURE (exact)			
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F



* SI is the symbol for the International System of Measurement

(Revised April 1989)

FOREWORD

This research was initiated by a joint request from the Federal Highway Administration's Office of Highway Safety, Office of Traffic Operations, and the Office of Highway Operations to determine the traffic safety and operations and the construction efficiency related to two traffic control strategies on four-lane divided highways. These strategies were to close one lane at a time or to close one roadway, build a crossover, and to operate the opposing roadway as a two-lane, two-way facility. The research was to prepare an information guide based on the research results.

The Research Report, volume I, FHWA-RD-89-209, provides the details of the research conducted and will have only a limited number of copies reproduced. The Informational Guide, volume II, FHWA-RD-89-210, provides basic study results for use by highway engineers. The reports will be distributed to the Transportation Research Information Service Network and Department of Transportation libraries and they will be placed in the National Technical Information Service (NTIS) to be available to interested parties. Both reports will be distributed to the regional and division offices with copies sent to the division offices for distribution to the State highway agencies.

R. J. Betsold
Director, Office of Safety and Traffic Operations Research and Development

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I. INTRODUCTION

Background

The Interstate freeway system is the backbone of the Nation's highway system. Interstate Freeways constitute only 1.25 percent of the ttotal highway network, but carries 20 percent of the traffic.

Construction of the Interstate System began in the late 1950's. There was, however, a need to begin to rehabilitate the system, particularly the pavements, as early as the 1970's. Rehabilitation requires that one or more lanes be closed. On four-lane freeways, which constitutes the vast majority of the Interstate System, two basic alternative traffic control strategies are primarily used during rehabilitation:

(1) Single lane closure (SLC). When one lane in one direction is closed resulting in little or no disruption of traffic in the opposite direction.

(2) Two-lane two-way traffic operation (TLTWO). When a roadway is closed and the traffic which normally uses that roadway is crossed over the median, and TLTWO is maintained on the other roadway.

Occasionally there is an opportunity to detour traffic to a parallel highway facility during paving operations, but in most situations one of the above two alternatives must be employed.

In the early 1970's, the majority of rehabilitation and resurfacing on four-lane divided highways and bridge structures was performed by using the TLTWO traffic control strategy. However, the concern for serious head-on vehicle collisions on the temporary two-way operation prompted the Federal Highway Administration (FHWA) to issue Emergency Regulations in 1978 which required positive barriers to separate opposing traffic flows.[1] The result was that most State agencies modified their traffic control plans and began to emphasize the use of the SLC because of the prohibitive cost of positive barriers at the time.

Recognizing the States' concerns, FHWA in 1982 modified the Emergency Regulations to permit TLTWO with alternative separation devices (other than positive barriers) subject to approval of channelizing devices by the States and FHWA.[2]

Highway construction and maintenance work zone productivity is influenced by factors such as the work environment, the quantity and quality of personnel and equipment and the methodology used in the work setting. Changes in any of these factors may either raise or lower productivity depending upon the change.

The traffic control approach selected affects the work zone environment and thus has a direct influence on work productivity. At every roadway work zone there is competition for lateral space (right-of-way) between the needs of the work itself and the requirement for moving traffic as safely and efficiently as possible. As space for the roadwork increases, there is a comparable reduction in lateral space available for traffic, and vice-versa. In the case of the above two traffic control strategies on four-lane freeways, SLC provides the contractor with less work space, but more space is available for moving traffic.

Another influencing factor is that the contractor must work adjacent to traffic. The SLC strategy usually increases the amount of time required by the contractor to complete the rehabilitation project. The TLTWO strategy allows the contractor total use of one side of the freeway and therefore provides the contractor with considerable flexibility in terms of construction methodology. Thus, the contractor can normally complete the work in less time. However, having two lanes closed (one in each direction) may be more disruptive to traffic and may result in significantly higher traffic congestion and motorist delays in areas where one lane capacities are approached.

The important issue in selecting between the SLC and TLTWO traffic control options, is the point at which one of the two becomes more economical from the standpoint of the total cost: construction cost plus road user cost (i.e., travel times, accidents, motor vehicle operating costs). Although there has been much speculation as to which of these traffic control approaches is more desirable for various types of construction and traffic volume levels, highway agencies and construction contractors need better data and guidelines to objectively select the most appropriate approach. The decision should be based on such items as type of construction, project duration, traffic volumes, cost of construction, and cost of traffic controls.

Objectives

The objectives of the reseach study were to:

(1) Determine the costs (construction and road user costs) and safety impacts associated with traffic control through work zones on four-lane divided highways using SLC versus TLTWO; and

(2) Prepare an informational guide for highway agencies and contractors to assist them in selecting the most cost-effective of the two traffic control strategies for proposed construction projects.

Scope

The research involved collecting and analyzing construction costs, traffic control costs and accident data from 51 construction projects on four-lane rural freeways where either the SLC or TLTWO traffic control strategy was used. Data were obtained from 11 states (Arizona, California, Florida, Kentucky, Louisiana, Michigan, North Carolina, Ohio, Oregon, Utah and West Virginia). There originally were 9 participating states until projects in California and Ohio were added.

The original intent was to conduct field studies to collect data to measure construction zone traffic capacity and estimate road user costs (travel time and motor vehicle operating costs) at 20 of the above construction projects. The traffic demands, however, were lower than the roadway capacities (or project construction had been completed) at 48 of the 51 selected projects and, therefore, traffic congestion was not anticipated at these sites. Thus, it was not possible to collect the appropriate field data. As an alternative, the researchers located and conducted field studies at 22 other construction projects where State highway agencies stated that traffic congestion would indeed occur. Field studies were conducted in 11 states (Arizona, Florida, Kansas, Kentucky, Michigan, Minnesota, Ohio, Oklahoma, Texas, West Virginia and Wisconsin).

The research thus included studies in 16 states. However, contacts with a number of other States in the search for field construction sites where traffic delay could be measured and studied.

Previous Work

Construction and Traffic Control Costs

In 1981, FHWA funded a research project dealing with improvements and new concepts for traffic control in work zones, and part of the project was devoted to the issue of traffic control on four-lane divided highways. The results were presented in a report titled, "Effects of Traffic Control on Four-Lane Divided Highways."[3]

The researchers conducted 9 case field studies (4 SLCs and 5 TLTWOs) on divided highways in Texas and Oklahoma with characteristics described in table 1. Data were collected at each site to assess (1) worker productivity; (2) job duration; (3) construction costs; (4) traffic control costs; (5) highway user costs; (6) accidents; (7) conflicts; and (8) capacity.

Attempts by the researchers to obtain the actual construction costs and traffic control costs for each of the nine construction

Table 1. Site characteristics.

Site	Location	Type of Work	Traffic Control Plan[a]	Hourly Volume[c] (Range)	Left Side TCD[b]	Right Side TCD[b]	Taper/ Crossover TCD[b]	Available Travel Width (ft)	Length of Closure (ft)	Length of Bridge (ft)
1	Leona, TX	Concrete Pavement Repair	SLC	225 - 280	Cones	-	BL	22.0	600	-
2	New Braunfels, TX	Pavement Resurfacing	SLC	705 - 875	Cones	-	Cones	22.0	6,900	-
3	Amarillo, TX[e]	Bridge Repair	TLTWO	1080 - 1795	PCB	PCB	BA	18.0	3,400	400
4	Amarillo, TX	Bridge Deck Repair	SLC	175 - 240	BR	Cones	BL	19.0	2,400	225
5	Carthage, TX	Pavement Reconstruction	TLTWO[f]	165 - 210	PM	-	BA	12.0	12,000	-
6	Oklahoma City, OK	Overhead Structure Repair	TLTWO	1275 - 1810	PCB	BR	DR/PCB	15.0	3,100	-
7	Oklahoma City, OK	Bridge Repair	SLC	250 - 350 1020 - 1890	PCB	-	DR/PCB	15.0	2,500	990[d]
8	Edmond, OK	Base Excavation and Pavement Resurfacing	TLTWO	600 - 960	Tubes	-	DR/PCB	20.0	22,700	-
9	Oklahoma City, OK	Bridge Repair and Pavement Resurfacing	TLTWO	550 - 680	Tubes	-	DR/PCB	20.0	25,500	-
Test	Dallas, TX	Bridge Repair	SLC	1600 +	Cones	-	BR	15.0	2,135	200

[a]SLC - Single-lane Closure.
TLTWO - Two-lane, Two-way Operation.

[b]PCB - Portable Concrete Barrier.
BA - Barricades.
BL - Barrels.
BR - Bridge Rail.
DR - Drums.
PM - Pavement Markings.

[c]In direction of lane-closure or crossover.

[d]Two bridges (270 and 160 feet long) 560 feet apart.

[e]Normal 6-lane freeway

[f]Crossover accomplished by exiting roadway, crossing an overpass, and reentering roadway using off-ramp on opposite side.

ft = feet

projects and the estimated costs for the alternative traffic control strategy (TLTWO if the SLC was actually used and SLC if the TLTWO was actually used) were not totally successful. Although, construction cost data (table 2) were obtained for all nine sites, cost information for the alternative traffic control strategy was obtained for only 3 of the 9 sites. The highway agencies and the contractors indicated they did not have the resources to produce confident estimates for the other six sites.

Using the contractors' bid prices to determine the cost of traffic control also presents a problem in accurately estimating costs. It was found that the contractors' bids for traffic control were much lower than the actual costs.[3] For example, one contractor bid one dollar for traffic control on a $400,000 project.

After determining that traffic control bid prices were misleading, the researchers requested that the contractors and/or highway agencies provide a realistic estimate of what the traffic control costs would be for the selected strategy, and for the alternative traffic control strategy had it been used. These estimates are presented in table 3. Alternative cost data were available for 5 of the 9 sites. Contractors provided cost estimates for the actual traffic control costs for their projects. Traffic control cost estimates ranged from 4 to 39 percent, and on the average, were 15 percent of the total construction cost.

It was recommended that actual costs and estimated costs for the alternative traffic control strategy would have to be reviewed for many more construction sites to fully address the cost issue. FHWA subsequently provided funds to several States to develop the data base for a more complete analysis which is the purpose of the research discussed herein.

The researchers' findings of the cost analysis, even with the small sample, are generally consistent with another FHWA study conducted to evaluate traffic control and construction costs at 10 SLC and 4 TLTWO work sites.[4] The evaluation was based on project bids made during 1980-1981, and the costs quoted by the overall low bidder on each project. The projects ranged in size (i.e., total cost) from $400 thousand to $15 million.

The results showed that construction costs for the projects using the SLC approach averaged just over $364,000/mile of work, while construction costs using the TLTWO approach averaged nearly $1,170,000/mile. However, this finding does not necessarily repudiate the claim by some that the TLTWO reduces construction costs. It should be noted that two of the 4 TLTWO sites reviewed

Table 2. Comparison of job duration and construction costs for alternative traffic control approaches.

Site	Type of Work	Job Length (ft)	SLC Job Duration[a] (Days)	SLC Total Cost ($)	TLTWO Job Duration[a] (Days)	TLTWO Total Cost ($)
1	Concrete Pavement Repair	12	1	2,779		
2	Pavement Resurfacing	21,120	60	416,712	*	*
3	Bridge Repair	400	240[b]	1,162,683[b]	200	849,372
4	Bridge Deck Repair	225	6	70,012	5[b]	78,012[b,c]
5	Pavement Reconstruction	12,000	300[b]	3,500,000[b]	225	2,925,660
6	Overhead Structure Repair	3,100			200	1,589,859
7	Bridge Repair	430	130	996,708		
8	Base Excavation and Pavement Resurfacing	22,700			120	1,708,201
9	Bridge Repair and Pavement Resurfacing	25,500			270	5,195,980

[a]Contracted duration.

[b]Indicates alternative traffic control approaches.

[c]Contractor was working on bridges in both directions of travel. A TLTWO control plan would have prevented simultaneous work on both bridges, accounting for the higher cost for the TLTWO alternative.

*No estimate given because job was dependent on the ability of the hot mix plants to furnish materials. Hot mix plants could not furnish materials as fast as the contractor could handle.

ft = feet

Table 3. Comparison of estimated traffic control costs for alternative traffic control approaches.

Site	Work Performed by	Type of Work	Traffic Control Plan	Traffic Control Approach SLC ($)	Traffic Control Approach TLTWO ($)
1	State	Concrete Pavement Repair	SLC	1,798	N/A[a]
2	Contractor	Pavement Resurfacing	SLC	14,850	N/A
3	Contractor	Bridge Repair	TLTWO	N/A	12,000
4	Contractor	Bridge Deck Repair	SLC	10,500	38,500 [b]
5	Contractor	Pavement Reconstruction	TLTWO	225,000[b]	125,000
6	Contractor	Overhead Structure Repair	TLTWO	44,178[b]	113,356
7	Contractor	Bridge Repair	SLC	246,098	288,142[b]
8	Contractor	Base Excavation and Pavement Resurfacing	TLTWO	N/A	344,693
9	Contractor	Bridge Repair and Pavement Resurfacing	TLTWO	1,644,076[b]	287,595

[a]N/A - Not available.

[b]Indicates alternative traffic control approach.

during the latter study involved complicated and costly work, and thus the results may be somewhat misleading.

Road User Costs

Researchers made field measurements at the 9 sites in the FHWA study and conducted field studies at an additional 7 sites in Houston, Texas as part of a study sponsored by the Texas State Department of Highways and Public Transportation.[3,5] The latter studies were conducted at sites with high traffic demands. Highway user costs for each of the 16 study sites using a work zone queue and user cost evaluation computer model (QUEWZ).[6] Table 4 shows the user costs at work sites during periods when significant queues were present. Table 5 shows the user costs at the 9 work sites from the FHWA study by direction of travel during periods of the day when no significant queues were present.

Table 4. User costs (significant queues present).

Site	Direction of Travel[b]	Average Queue Length (mi)	Average Additional User Cost per Vehicle: Delay Cost ($)	Average Additional User Cost per Vehicle: Operating Cost[c] ($)	Average Additional User Cost per Vehicle: Total Cost ($)	Vehicle Cost Per Mile of Queue ($)	Average Vehicle Volume (veh/hour)	Average Hourly User Cost ($)	Average Hourly User Cost Per Mile of Queue ($)
7	CQ	0.66	0.53	0.11	0.64	0.96	1,407	895	1,356
Test[d]	CQ	0.728	1.32	0.11	1.43	1.96	1,700	2,424	3,329

[a]Totals may not match separate values due to rounding errors and weighting of each run by the corresponding traffic volume.

[b]CQ - Direction of crossover or lane closure while queue was present.

[c]Operating costs include vehicle running costs and speed change cycle costs.

[d]Located on Central Expressway in Dallas, Texas.

mi = miles

Table 4 shows that the average additional road user cost for sites with significant queues was $0.64 per vehicle in the direction of the lane closure. As shown at the bottom of table 5, the average additional road user costs (costs above what would normally be expected) with no significant queues was $0.11 per vehicle in the direction of the crossover and $0.08 in the opposite direction.

Graphs were developed which illustrate the relationships between hourly demand traffic volumes and user costs which resulted from QUEWZ model.[6] Figure 1 shows the relationship between

Table 5. User costs (no significant queues present).

Site	Direction of Travel[b]	Type of Traffic Control	Average Additional User Cost per Vehicle: Delay Cost ($)	Operating Cost[c] ($)	Total Cost ($)	Average Vehicle Volume (veh/hour)	Average Additional User Cost Per Hour ($)
1	C	SLC	0.03	-0.01	0.02	273	5
	O		<.01	<.01	<.01	286	<1
2	C	SLC	0.13	0.01	0.14	865	120
	O		N.A.	N.A.	N.A.	N.A.	N.A.
3	C	TLTWO	0.16	0.03	0.20	1,139	228
	O		0.14	0.03	0.18	1,249	220
4	C	SLC	0.04	0.00	0.04	204	9
	O		0.01	0.01	0.02	175	3
6	C	TLTWO	0.15	0.02	0.17	1,625	276
	O		0.13	0.01	0.14	1,621	229
7	C	SLC	0.07	0.03	0.10	1,114	117
	O		0.04	0.01	0.05	260	14
8	C	TLTWO	0.21	-0.06	0.15	943	145
	O		0.20	-0.09	0.10	496	61
9	C	TLTWO	0.12	-0.02	0.10	662	64
	O		0.11	-0.03	0.08	601	46
Average	C		0.11	0.00	0.11	853	94
Average	O		0.09	-0.04	0.08	684	55

[a] Totals may not match separate values because of rounding errors and weighting of each run by the corresponding traffic volume.

[b] C = Direction of SLC or crossover.
O = Opposite direction.

[c] Operating costs include vehicle running costs and speed change cycle costs.

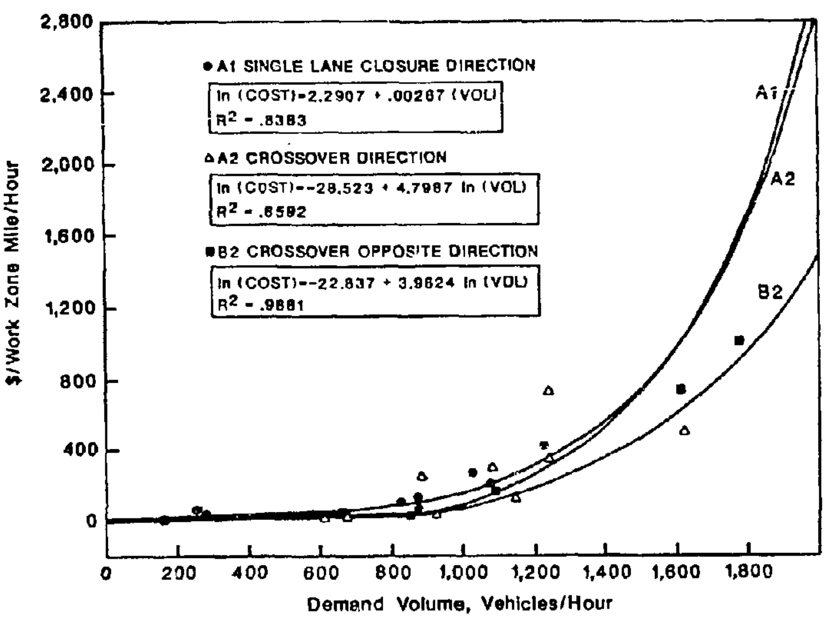

Figure 1. Additional hourly user costs per mile of work zone by direction of travel.

additional user costs per work zone mile and hourly demand volume for the SLC and TLTWO traffic control strategies. An accident analysis conducted using a limited data base indicated that the TLTWO sites studies generally had a better safety performance based on accident rates only.[3] Results of accident severity by traffic control approach were inconclusive because of the small sample sizes.

Separation Devices

In a related study for the American Concrete Pavement Association (ACPA), a researcher examined the effectiveness of various separation devices (other than positive barriers) for use during TLTWOs.[7] The researcher conducted a survey and developed a visual slide package and a separate publication in which he demonstrated observed techniques for separating opposing traffic flow during pavement improvement projects. Data were obtained from an 18-State survey of construction projects using the temporary TLTWO method of traffic control. A wide variety of techniques for separating flow (in addition to the positive barrier) where found to work satisfactorily without a detrimental effect on highway safety.

Additional findings from the study were as follows:

(1) FHWA developed criteria for effective channelizing devices that will be functional and durable in separating traffic flow during TLTWOs.[8]

(2) Tubular devices with double yellow centerline markings have been successfully used on projects with an average daily traffic (ADT) volume of 14,500.

(3) The experimental continuous raised asphalt divider developed by North Carolina has been successfully used on projects with an ADT approaching 28,000.

(4) There are limits on the length of temporary TLTWO sections because of driver impatience on long sections, but states have reported many projects using lengths greater than 5 miles. Frequent signs displaying distances to the end of the TLTWO are helpful.

(5) Raised reflective pavement markers in the centerline area are effective in deterring motorists from straying across the centerline.

(6) Rumble strips constructed into paved shoulders should be installed only after careful evaluation and should be avoided when temporary shoulder lane use is anticipated in future pavement maintenance work.

The above project research and studies serve to demonstrate the number of complex variables involved in determining which of the two methods to employ in handling traffic on four-lane divided highways. When pavement rehabilitation and maintenance projects must be implemented in the efforts to preserve the integrity of the Nation's extensive and essential highway transportation system, agencies must carefully consider all alternatives involved in their traffic control design decisionmaking.

II. RESEARCH AND STUDY APPROACH

Identification of Data Needs

Construction and Traffic Control Costs

The procedure for comparing the costs of construction and traffic control for the two alternative traffic control strategies--SLC and TLTWO--was to obtain cost data from the highway agency for each of the 51 selected construction projects. Cost estimates were then made by the researchers for the alternative traffic control strategy to the one used by the agency. For example, if SLC was used by a highway agency on a specific project, all of the cost data would be obtained from the agency for the construction project. The researchers would obtain other relevant information from the agency and then estimate the cost of the construction assuming that the TLTWO traffic control strategy was used. The data necessary to fully assess the construction and traffic control costs for the two alternative traffic control approaches included the following:

(1) Type of construction (bridge rehabilitation, pavement rehabilitation, etc.);
(2) Location of construction (rural or suburban);
(3) Length of bridges or roadway under construction;
(4) Type of traffic control plan (SLC or TLTWO);
(5) Traffic control plan detailing traffic control devices, detours, etc.;
(6) Type of traffic control devices for advance warning, channelizing, separating traffic from the work, separating opposing traffic on TLTWO, etc.;
(7) Construction phasing details;
(8) Total construction cost;
(9) Bid item quantities for traffic control measures:
    (a) Median crossovers
    (b) Separation of traveled way from construction
    (c) Separation of opposing traffic (TLTWO);
(10) Construction procedures and equipment;
(11) Factors that led to the choice of the traffic control approach; and
(12) Agency policies.

Road User Costs

Road user costs that are priceable can be classified into travel time costs, motor vehicle operating costs and accident costs. The data necessary to fully assess road user costs for both traffic control alternatives include the following:

(1) Traffic volume through the work site (to determine work zone capacity);
(2) Demand traffic volume upstream of the work site (to determine delay);
(3) Duration of the construction (number of days);
(4) Duration of lane closures and crossovers;
(5) Length of queues on typical days;
(6) Time and duration of peak periods other than normal weekday peaks (e.g., recreational traffic);
(7) Length (distance) of closure or crossover;
(8) Available right-of-way for travel lanes (including shoulders);
(9) Available right-of-way for construction (work space);
(10) Length of detours (if any);
(11) Traffic distribution by vehicle type;
(12) Number of people within vehicles;
(13) Number and type of vehicle accidents (before and during construction); and
(14) Number and type of worker accidents.

Coordination With State Representatives

Initial Contacts With States

The principle investigator for the study telephoned the State representatives of the 9 participating States to briefly discuss the nature and scope of the research project. During the discussions, a brief description was presented outlining the data needs, responsibilities of the researchers and the agency, and general requirements for candidate projects to be considered for study. The State representatives assigned to the project were employed within one of 4 typical agencies of a State transportation/highway department:

(1) Traffic engineering unit. (5)
(2) Research unit. (2)
(3) Construction unit. (1)
(4) University research program. (1)

Followup letters were transmitted to each State representative confirming the telephone discussions, describing the scope of the research project and the candidate study project selection parameters, requesting submission of 10 candidate projects to be listed on forms as shown in figure 2. Preliminary arrangements and approximate dates were scheduled for visits to each State representative to review procedures and candidate projects, visit construction sites of logical study projects and begin project file data collection. Arrangements were also made to meet with pertinent personnel within the State transportation or highway agency that could provide additional data and information necessary for the research.

There has been emphasis by the FHWA to encourage States to use more unit prices for work associated with traffic control in work zones. Unit price bids provide more flexibility and receptiveness by contractors to implement unforeseen changes in Traffic Control Plans (TCPs) during construction even though there is more documentation required. Although there is a trend to use more unit price bid items, there are a variety of practices by State transportation/highway agencies in the use of lump sum or unit prices for bidding traffic control items of construction work. The FHWA contracting officer's technical representative for the research project provided the researchers with a recent summary of State practices gathered by the FHWA. These practices were summarized for individual participating States by the researchers and forwarded to each State representative. This was done to verify current practices and become more familiar with specific practices in each State to simplify analysis of construction costs.

Meetings With State Representatives

The principal investigator and/or the traffic engineering consultant traveled to each participating State to initially meet with State Representatives. A review of research objectives and discussions were typically held with the State Representative and meetings arranged with pertinent individuals that would be involved in the design, construction and data collection process. Typical State agency personnel contacted were the following:

(1) Traffic Engineer.
(2) Design Engineer.
(3) Construction Engineer
(4) Planning Engineer (traffic data collection).
(5) Pavement Design Engineer.
(6) Estimating Engineer (alternate TCP estimates).
(7) Safety Engineer (accident data).

Meetings were held with each of the above individuals or their representatives to become familiar with the individuals involved in the normal design/construction process for each participating agency. Typical forms, status reports, construction cost

Candidate Project Form

FHWA CONTRACT DTFH61-86-C-00064
"Constr. Costs & Safety Impacts of Work Zone TC Strategies"
Rural Four-Lane Divided Highways

1. State Agency Name *Utah* Candidate Proj. # 4

2. Highway Route I-15 Project Identif. No. I-R-15-3(22)112

3. Location: No. Beaver to Wildcat

4. Project Distance From Dept. HQ: 200 Miles

5. Date of Project: Year 85-86 Completed [ ] Active [X] Planned [ ]

6. Type of Project:

   - [ ] A. Asphalt Concrete Pavement Resurfacing/Recycling
   - [ ] B. Pavement Cracking & Seating
   - [X] C. Concrete Pavement Overlay/~~Inlaid &/or Recycling~~ *on Asphalt*
   - [ ] D. Concrete Pavement Restoration
   - [ ] E. Bridge: [ ] Repair [ ] Replacement
   - [ ] F. Major Highway Reconstruction
   - [ ] G. Other (Describe)

   Specific Comments: TCT.NO - *Conc. Barrier Separation - FHWA R*

7. Alternative Design Analysis Performed To Choose Method of Traffic Control? [ ] Yes [X] No

   Comments

8. Average Daily Traffic: 5750 9. Length of Project: 8.8 Miles

10. Project Construction Period: 18+ Months *Complete This Year (?)*

11. Cost of Project (Actual or Estimated): 11,229,000

12. Please list any other comments:

13. Date Form Completed: 8-21-86

Figure 2. Sample candidate project form.

monitoring, accident data formats and frequencies and other pertinent information were obtained for future reference and use during the research project.

After meeting with the other agency personnel a meeting was then held with the State representatives and/or responsible personnel to review skeleton construction plans for each candidate project to determine applicability for inclusion within the research study. The majority of the States had few projects to select from that involved the TLTWO traffic control methodology. Since the research required approximately one-half of the study projects (25) to be TLTWO, considerable time and effort was devoted to locate all possible projects that employed this strategy, even if TLTWO was employed only a portion of time during construction of particular projects.

Discussions were held with State representatives regarding their practices and policies for use of TLTWO and any State policies or legislation that should be considered in the analysis. Preliminary reviews of the candidate projects furnished by the States during these meetings indicated a wide variety of four-lane divided highway construction projects. It became apparent that selection of only two or three categories of types of construction for study would not include each construction type project classification for which the two traffic control strategies were employed.

Also during these initial visits to the States, efforts were made to select planned and active construction projects for study that would have sufficient traffic demand through the work zones to cause traffic delays that could be measured in the field. General criteria provided to the States to screen these projects were those with an ADT of 25,000 or more. Experience has shown that directional peak hour volumes of 1,500 which is considered to be near the capacity when one lane is closed. Thus, delays would be expected on approaches to and through the construction work zones.

Preliminary On-Site Inspections

Following meetings with the State representatives and selection of some projects for inclusion in the study, arrangements were made to visit active construction projects within each State, where possible. Field inspection of the projects were made and meetings held with project/resident engineers to obtain additional significant information concerning project construction activities.

The meetings were very beneficial, and in some cases, it was possible to obtain lane closure dates and times for use in project analysis. Other information collected from the project engineer included problems with handling traffic, construction, significant changes during construction, accident data and other significant occurrences during construction.

Agreements With States

Final meetings were held with State representatives during the visits to recap, review and confirm agreements reached concerning data needs the State was to furnish, including deadline dates for receipt of data for each study project selected during the meetings. Criteria was also reviewed and projects requested where delays had been or would be occuring through work zone sites.

Written reports were completed after each State visit to document agreements reached during the meetings. A file of candidate projects was then developed for each State which documented pertinent features for each project to be used in the selection of overall projects and classification of projects by type of construction. A sample of this file is shown in figure 3.

OREGON - Candidate Projects

Description/Proj. No. Location	Yr.	TCP	Dur. (Mos.)	Length (Miles)	Cost ($000)	ADT
A. Pavt. Cracking/Seating						
B. Concrete Overlay/Recycling						
1. I-5 Albany, Linn Co.	84C	TLT	28	7.0	$12.6	24200
IR-5-4(95)228 (3 Intges kept open, ex pavt removed)						
2. I-5 NB Goshen to Saginaw	84C	TLT	19.7	13.2	$6.7M	23700
IR-5-3(132)174 (NB Only, Asph overlay also removed, 3 Int. kept open)						
5. I-5 SB Elkdhead-Rice Hill	84C	*	23	7.1	$2.1M	13100
IR-5-3(131)147 (* Partial detour +TLTWO w/conc bar)(recycled)						
6. I-84 Meacham-La Grange	86C	Both	6.1	?	$3.8	5550
IR-84- (Pavt Recycled)						
C. Concrete Pavt. Restoration						
4. I-5 Grant's Pass &South	86A	Both	16.6	15.5	$4.2M	18300
IR-5-1-(111)043 (Some conc bar in LC, TKTWO w/bar)						
D. Asphalt Conc. Overlay						
8. I-84 east of Portland	87P	LC	4	?	$0.1M	?
E. Bridge Deck Overlay						
F. Bridge Deck Replacement/Widening						
3. I-84 Warrend.-Lyento St Pk	85C	LC	12.3	20+	$0.4M	12300
IR-84-2(16)36 (6 Br Widened, Culvert Rep.)						
G. Reconstruction						
7. I-5 Mackenzie r.-Willemtt	86A	TLT	24	4.4	$18.5	31500
IR-5-4(102)193 (Widen to 6 lanes betw intges., Partial 4LtWO)						
H. New and Intrchange Construction						

Figure 3. Sample candidate project file.

III. STUDY PROJECT SELECTION PROCEDURES

Construction Study Projects and Classification

The following criteria were used to select construction projects for study and determine project classifications by type of construction:

(1) A minimum of 50 construction projects were to be studied.

(2) All construction projects must be on rural four-lane divided highways.

(3) Fifty percent or 25 study projects or more were to involve the TLTWO traffic control strategy.

(4) Projects were to be selected such that 20 were planned or active construction projects that could be field studied for traffic delays through the work zone.

(5) An alternate traffic control analysis was required for each study project for the strategy that was not employed during construction of the project.

A total of 109 candidate projects were identified by the 9 States for consideration and inclusion within the overall study. Because of the interrelationship of the above criteria, it was necessary to combine the process of selection of the 50 study projects with the classification of projects by type of construction. Table 6 shows an example of a computer file developed for one classification type.

Most rural candidate projects identified by the States did not experience daily traffic delays, either during morning or evening peak hours, that are normally associated with urban or metropolitan population areas. The few projects that experienced or could be expected to generate daily predictable delays were located in the fringe areas of metropolitan population centers. Others were found to be those involving heavy tourist or holiday traffic associated with weekend travel. As a result of these findings, it was necessary to disassociate the selection of most field traffic study sites for measuring delay from the overall construction study projects.

Another problem experienced was that a number of the participating States were hard pressed to find 4 or 5 candidate construction projects that utilized the TLTWO method of handling traffic. Therefore, it was necessary to select some projects for study that were not the typical projects involving routine lengths of highway with resurfacing, reconstruction or bridge construction work. To satisfy the requirement of studying at least 25 projects involving TLTWO, nearly all identified candidate projects that

Table 6. Candidate projects sample listing -- reconstruction.

G. RECONSTRUCTION (24 Projects)

Cand No	Route/Location Description	Yr.	TCP	Dur (Mo)	Lngth (Mi.)	Cost ($M)	ADT	Alt TCP	Fld Stdy	Study Pot
Arizona (3)										
1.	I-40EB RiordonOP-US89A	86C	TLT	8	4.1	6.4	9400	N	N	
	IR-40-3(62) MP191 (Eastbound Only)									
4.	I-10 Gila R Br Apprs	86C	LC	5	0.1	1.1	19000	N	N	
	ER-10-3(212) MP304 (Wide Veh Detour)									
5.	I-8	86C	?	7	5.1	2.2	5500	N	N	Yes
	IR-8-2(86), MP 160.8 (+ Overlay, GR & Culvert)									
Florida (5)										
2.	SR80 Palm Beach Co	85C	LC	635	5.6	10.0	5800	N	N	Yes
	93120-3524									
3.	SR710	85C	LC	400	5.5	4.4	8010	N	N	
	93310-3512									
4.	US29(SR95) LanogCr-C4A	86A	LC	340	2.1	4.3	6000	N	N	
	418060-3519 (Bid 8/87, Overlay, Guard Rail, Culvert)									
5.	SR95 CR4A-CR4West	86A	TLT	470	3.0	4.9	4900	N	N	
	48060-3515 (Widen 2 to 4 lanes)									
17.	SR710(BeeLine)	84C	LC	346	3.4	2.6	6260	N	N	
	93310-3511 (So of Palm Beach Gardens) (Two Lanes Added)									
Kentucky (1)										
2.	US127 Boyle Co	87P	TLT	?	?	?	12000	N	N	Yes
Louisiana (7)										
5.	I-12 Us61-O"Neal	86A	2L	13	5.0	15.2	48420	N	N	No
	454-01-40 (Widen 4 to 6 lanes, not eligible)									
6.	I-59 Pearl R Br-Miss L	86A	TLT	23	5.0	10.6	22190	N	N	Yes
	453-01-28									
7.	I-20 McIntyre-DixieInn	86A	TLT	8	2.6	4.9	27590	N	?	Yes
	451-03-37									
8.	I-20 Ruston-Choudrant	86A	TLT	14	7.0	11.9	23870	N	N	
	451-05-59									
9.	I-20 Rayville-Holly Rg	86A	TLT	12	6.7	10.5	[illegible]540	N	N	Yes
	451-07-30 (Asphalt Divider)									
10.	I-20 SR17-SR577	87P	TLT	13	6.0	8.1	13[illegible]	N	N	
	451-07-29, -08-29									
13.	I-10 Sulphur-Westlake	87P	TLT	20	5.0	10.8	32000	N	?	Yes
	450-91-42 (Funding Delay?)									

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utilized TLTWO during construction were selected for study. Some of the projects used this strategy for only a portion of the construction work. Several of these projects were interchange reconstruction or new construction. Other major reconstruction projects included in the study used both the SLC and TLTWO traffic control strategies in separate stages of construction to accomplish the required project work.

During the preliminary meetings with several States, the researchers were advised that the TLTWO method of handling traffic on certain projects was the only strategy available to perform the construction work necessary for the construction improvement project. This was specifically applicable to concrete pavement recycling/overlay projects. The researchers took this to mean that it was not economically feasible to use the SLC strategy, but that an alternate TCP analysis could be undertaken for several typical projects to verify the statements made.

One other significant factor in finalizing the number of construction projects, as well as classifying the projects, was an unfortunate delay incurred by the State agencies in implementing the construction study projects because of funding problems. This was primarily caused by a delay in passage of the 1987 Federal Surface Transportation Act. As a result it was necessary to eliminate several construction projects that were postponed indefinitely and replace them with other candidate projects that were completed or scheduled for construction. Additional projects that were found desirable for study were located in Ohio and California. The final selection of construction study projects and classification by type of construction are listed in table 7.

Table 7. Classification and selection of study projects.

Classification Code	Type of Construction	Number of Study Projects
A	Concrete Pavement Recycling/Overlay	6
B	Concrete Pavement Restoration	5
C	Asphalt Concrete Pavement Overlay	13
D	Bridge Deck Overlay	4
E	Bridge Deck Replacement/Widening	6
F	Reconstruction	11
G	New/Interchange Construction	6
		51

Traffic Study Projects

The original plan was to collect the field data for each of the construction study projects to estimate the construction costs using each of the alternative traffic control strategies. The data would then be analyzed and road user costs associated with motorist delays and operating motor vehicles would be estimated for the entire duration of the construction project for each of the alternate traffic control strategies. However, traffic volumes on all but 3 of the candidate projects were not high enough to generate traffic congestion through the work zones. (It was necessary that traffic congestion exist in order to measure traffic capacity at each construction site.) Since most of the selected projects did not experience delay, it was necessary to seek other projects in the United States for traffic study to develop a data base that could be used for estimating these costs.

The decision was made to conduct traffic studies and collect field data at other construction sites where congestion was anticipated. Contacts were made in several States to locate suitable sites for field data collection. The process was difficult in itself because State agencies were not able to locate many four-lane divided highways where congestion was being experienced or anticipated. Eventually 25 sites were identified for traffic studies, 3 of which were construction study projects, where agencies were confident that congestion would occur.

IV. DATA COLLECTION PROCEDURES

Construction Study Projects

The researchers collected the necessary data in 8 of the 9 participating States. The FHWA negotiated a contract with the State of Kentucky and the University of Kentucky to provide the data for that State. The following procedures were used in collecting data for the study projects.

<u>Project Design Information</u>

Collection of design data was initiated during the initial meetings of the principle research engineers with the State representatives, once candidate projects were reviewed and certain projects had been selected during these meetings. Preliminary data collection forms were developed for each project to monitor the status of data received for each project. A sample is shown in figure 4.

STATE: ARIZONA
Project ID: #6

FHWA #: IR-10-6(103)
Location: IR 10 - Ocotillo Rd.

Requested Data:	Status:	Comments:
TLTWO	✓	
Single Lane Closure		
Const Start Date	Oct 12, 1986	
Const. Comp Date	Jan 1, 1987	
Award Cost Total		EST. $1,537,629
Award Cost T. C.		
Final Cost Total	(1)	Not available yet
Final Cost T. C.	(1)	Not available yet
Initial Bid Tab	Nov 18, 1986 ✓	
Final Bid Tab		
Acc Data Prior	✓	10/12/83 to 10/12/86
Acc Data During		
Const. Plans	Partial ✓	all but shts 40-44 (Structure shts)
Tra Cont. Plan		
Alt. T. C. Plan		
Resident Engineer	Noland Durnell	(602) 428-5470
Lane Close Length	✓*	~~not available yet~~ * rec'd (ltr 10 Sept 87)
Lane Close Duration	✓*	~~not available yet~~ * rec'd (ltr 10 Sept 87)
ADT thru Work Zone	12,000	
Misc. Gen. Inform:		
Stand. Specs.		
Sup. Specs.		
Stand Drawings		
Typical Notes		

Notes:
(1) 13 Sept 87 - final costs should be available

Date: 25 July 87
Revisions:
13 Sept 87
16 Sept 87

Figure 4. Sample preliminary data collection form.

Typical information collected for each project is as follows:

(1) Standard Specifications and Standard Drawings

This information was obtained to determine basis of payment for construction costs and typical details for work to be performed for each project. In many cases, particularly for older projects for which construction was completed, it was necessary to obtain additional standard specifications and standard drawings applicable to projects at the time of construction.

It was also determined during the analysis phase that there were supplemental specifications applicable to selected projects which were obtained as needed.

(2) Construction Plans

Partial sets of construction plans were obtained in order to evaluate proposed construction work and associated costs for comparative purposes. Typical plan elements obtained were:

(a) Title sheet.
(b) Schematic plan of project.
(c) Typical sections.
(d) General summary.
(e) General notes.
(f) TCPs.
(g) Line sheets.
(h) Bridge plans (bridge projects).

(3) Pavement Design

Since all construction projects studied involved improvements, rehabilitation or maintenance of highway pavements, information on history and background of the pavement design decisions were pursued on most of the projects excluding routine asphalt concrete pavement overlays (resurfacing) projects. This information was obtained for use in cost and alternate traffic control plan analysis.

The data for projects selected at that time were obtained through meetings with State pavement design engineers or their counterparts during the preliminary meetings with the participating States. In cases where projects were later selected for study, this information was obtained during followup visits or by telephone.

(4) Alternate TCP Design Analysis

History on the documentation of the design process and consideration of the two alternate traffic control strategies was pursued for each study project. It was found that there was very little documentaton available in the States' files on alternate traffic control design analyses of construction projects selected for study. However, data was available on several projects in North Carolina.

Most States indicated they pursued considerable design deliberations on alternate methods of traffic control. However, the researcher was advised that the method was generally determined by the type of construction work required and history of past practices.

(5) **Location of Project**

Information on the general location of projects was obtained without any great difficulty. Most construction plans have maps on title sheets or schematic plan sheets that are helpful in identifying the specific locations of projects. However, the location of projects by sign milepost (distance of the project from the beginning of the sign route within the State) was not readily available in several of the States. Since almost all of the study projects were on interstate freeways, it was initially believed that the sign milepost would be the most logical basis for project locations. This was not recognized as a problem until accident data was received and reviewed for correlation with the project limits. Project limits for construction study projects had been previously furnished to the States to request the accident data.

Some States do not use the sign milepost method for identifying construction project locations, but have other methods of correlation with accident data bases. Some use a county milepost system for identifying projects, while others have a completely separate milepost system for identifying construction projects and accident locations. One State used only physical features, such as an intersecting route or grade separation structure. As a result additional time was required to verify project limits; in some cases it was necessary to obtain additional accident data to match revised construction-related limits for consistency.

Average Daily Traffic (ADT)

The most current ADT was obtained for each construction study project. In many cases this traffic information was not necessarily current traffic or actual traffic at the time of construction because traffic counts for most highways are not taken annually. The data was the best information available from the States and was used in determining accident rates for each study project.

When projects included several interchanges, there were variations of the ADT provided within the same project construction limits. For purposes of the study these traffic volumes were averaged in order to use a single ADT volume for the project.

Project Construction Information

(1) Bid Proposal and Special Provisions

Both of these contract documents were obtained for most study projects. The information was useful in identifying special bid items of work that were not included in standard specifications but were significant in the traffic control cost analysis. During the research contract period some States were in transition from the historical lump sum to the unit price basis of payment for traffic control items of work. The information obtained was essential to the analysis of the traffic control costs because the standard specifications were superseded by the contract plans and documents in some projects. The proposal and special provisions were also used for reference in analysis and estimating construction costs for alternate traffic control strategies.

(2) Awarded and Final Construction Costs/Quantities

Bid tabulations for construction contract award and final costs were obtained for each project, except for those projects that were not completed or final costs were unavailable within the time frame for the research study. In these few cases awarded or near final costs were used. Obtaining awarded and final costs enabled the researchers to determine any significant problems or changes in work occuring during construction of the project. For example, on one project rapid deteriation of pavement doubled the pavement patching quantity from the bid estimate.

(3) Dates of Construction

The dates of construction were obtained for all projects for use in defining accident data analysis periods. Although obtaining this data was not anticipated to create any difficulties, there was not a uniform understanding by the States of the actual dates of construction desired when data was requested by the researchers. The desired start date, for example, was the date when the contractor actually started construction. Some States furnished the date that the project was awarded. Similarly, the completion date desired was the date of acceptance of the project, not the date that the project was finalled out (all quantities and costs verified). It was necessary to verify these dates with the States to assure that the accident data obtained was accurate for the actual construction period for the project. Considerable time and effort were needed to determine the dates of construction, which delayed the accident data collection and analysis.

(4) Number and Duration of Lane Closures

This information was requested to assist in estimating delay and road user costs through congested work zones. The data were difficult to obtain for completed projects, particularly those involving SLC type traffic control. This information is not normally documented in the files for construction projects, except when TLTWO is employed, or when SLCs involve the use of lengthy sections of positive barriers. TLTWO and SLC strategies involving positive barriers are more stationary and require a stage of construction with a traffic operation pattern that remains in place for a period of time. In these cases documentation of the date and time are more definite because there is an extensive amount of field work involved to install or remove the lane closure.

To obtain lane closure data for SLC traffic controls, forms were developed for use in planned and active construction projects. A sample form is shown in figure 5. Data were collected where possible on projects for which the forms were available in time for documentation by construction personnel. Without measurable traffic delays through a great majority of the construction study work sites, the minor differential in user costs between TLTWO and SLC for these projects was not considered to have a significant impact on the research performed.

(5) Project/Resident Engineers

The names and telephone numbers of responsible project or resident engineers were also obtained for all construction study projects. The information proved very helpful in the data analysis stage when it was necessary to obtain additional history on construction problems associated with a particular project. It was also useful to make contacts when it was discovered during the analysis phase there were extensive changes in construction and traffic control costs or quantities during construction.

<u>Coordination of Data Collection</u>

To monitor the data collection as it progressed during the research study, computer files of data needs were developed for each State and construction study project. A sample of the data needs form is shown in figure 6.

Data needs were updated frequently as data were received from the States. Periodically, telephone calls were made with reminder letters sent to the State representatives along with data needs forms to confirm additional data that were requested. Because a number of study projects were actively under construction, a considerable amount of effort was expended by the researchers to obtain current construction progress information. Final cost analysis of each construction study project was dependent on receiving the most recent status of the completion of each project.

FHWA PROJ. # DTFH61-86-C-00064 LANE CLOSURE DATA

STATE ____________ CONSTRUCTION PROJ. # ____________

LOCATION ____________

DATE	MILEPOST & DIRECTION	TIME AM/PM	LANE CLOSURE		TLTWO or SINGLE LC	REMARKS
			PLACED IN OPRN	REMOVED		

Form Completed by: ____________ Date ____________

Figure 5. Sample lane closure data form.

Federal Project DTFH61-C-86-00064

STATUS OF STUDY PROJECT DATA NEEDS

Louisiana

8/15/88

E Proj. #1, US 190, Baton Rouge Parish TLT Start - 5/27/86
Proj. 7-10-28, BHF-03-1(009) Completion - (84% as of 3/1/88)
91% of time
NEED: 1. Actual Completion Date
2. Final Bid Tab
3. Acc. Data - During
1/1/88 - Completion
4. Lane Closure data
Resident Engr. - James C. Tadie, 504/342-7571 or 7570

C Proj. #3, I-10, SR 22 Ascension/St.James Par. LC Start - 3/17/86
Proj. 450-11-24, 450-12-13 Completion - 6/30/87
IR-10-4(095)186 & IR-10-4(096)190

Resident Engr. - Gordon Nelson, 504/675-5320

C Proj. #4, I-12 Tangipahoa Parish LC Start - 1/27/86
Proj. 454-03-21, IR-12-1(078)040 Completion - 7/17/86

NEED: 1. Lane Closure Data
Resident Engr. - Joel McWilliams, 504/345-7590

F Proj. # 6, I-59, St. Tammany Parish TLT Start - 2/19/86
Proj. 453-01-28, IR-59-(019)5 Completion - (59% as of 3/1/88)
54% of time
NEED: 1. Final Completion Date?
2. Acc. Data During Construction
1/1/88 - Completion
3. Lane Closure Data
4. Final Bid Tab
Resident Engr. - Raycent Chu, 504/892-1458

Figure 6. Sample data needs form.

Accident Data

Collection and verification of the accuracy of data collection parameters was probably the most difficult of the data collection tasks. Data were obtained for projects 3 years before construction and during the construction period for each project. Accident data was obtained within project limits and extending approximately 1 mile outside these limits in both directions of the highway for most study projects.

A separate overall computerized accident data status summary was maintained to list the date of receipt of data, data furnished to the statistician consultant and outstanding data needs. A sample of the summary is shown in table 8. Status, completeness and accuracy of the data were reviewed frequently, and the data needs transferred to the project data needs files for transmittal to the States with reminder letters of remaining data needs.

Once sufficient data were received, it was reviewed for accuracy and forwarded to the statistician consultant for reduction and analysis. Upon initial review of the data received from the States, it became readily apparent that each State used a different data base format for their printouts of accident data summaries. It was necessary for the statistician consultant to develop a common data base for reduction and use of the data for comparative analysis of the two traffic control alternative strategies. Specific aspects of this are discussed in the accident data analysis section of this report.

Considerable coordination was needed with the States to obtain accurate data location limits and periods for which data was needed for each project before accident data could be analyzed for the research study.

Supplemental Data Collection

Very early during the preliminary analysis of the construction and traffic control costs, it was determined that more complete data were needed, and that more complete background information on construction progress and history was essential to the cost analysis for each project.

A pilot visit was made by the principle investigator to one of the States to meet with construction personnel in the headquarters office. The meetings yielded valuable background information and documentation on study projects including change orders and answers to a number of questions concerning substantial changes in items of construction work and costs. The meetings yielded such excellent results that additional meetings were arranged with construction personnel in most other participating States to obtain more detailed information. The meetings also

Table 8. Sample accident data status (Michigan).

ENB #	RT#	TCP type	PROJ LGTH (mi.)	START DATE MO/DA/YR	COMPLETE DATE MO/DA/YR	CONST. PERIOD (MOS.)	ACC. DATA BEFORE FROM MO/DA/YR	ACC. DATA BEFORE TO MO/DA/YR	ACC. DATA DURING FROM MO/DA/YR	ACC. DATA DURING TO MO/DA/YR	[5 SEPTEMBER 1988] COMMENTS
MI#A2	IR94	TLT	5.8	5/ 9/86	11/14/86	6	5/8/83	5/8/86	5/9/86	11/14/86	Data Complete* MP 3.89 - 11.60* MP 0.00 - 2.00*
MI#G3	IR69	TLT	2.02	9/28/85	(1988)		5/12/83	5/12/86	5/13/86	12/15/86	Need Data: 12/16/86 to Completion* MP 7.90 - 11.11* MP 0.25 - 3.15*
MI#D5	IR196	LC		7/30/86	11/ 8/86	3					Data Complete*
@MP2.27							9/17/83	9/17/86	9/18/86	11/8/86	MP 1.77 to MP 2.77*
@MP3.67							7/29/83	7/29/86	7/30/86	9/19/86	MP 3.17 to MP 4.17*
@MP4.70							7/29/83	7/29/86	7/30/86	10/10/86	MP 4.20 to MP 5.20*
MI#F6	IR96	TLT	8.2	3/17/87	11/13/87	8	3/16/84	3/16/87	3/17/87	11/13/87	Data Complete* MP 10.20 - 12.50* MP 0.00 - 9.70*
MI#F8	IR96	TLT	5.97	5/19/87	6/16/88	13	5/18/84	5/18/87	5/19/87	3/31/88	Need Data:4/1/88 thru 6/16/88* MP 2.60 - 10.60* MP 0.00 - 2.00*
MI#C10	IR96	LC	5.88	10/ 8/86	8/21/87	10	10/ 7/83	10/ 7/86	10/ 8/86	8/21/87	Data Complete* MP 0.90 - 10.80*

Available Data mailed to Texas - 7/9/88.
Additional Data mailed to Texas - 8/11/88.

* New Data Recieved from Michigan, 9/1/88.

afforded the opportunity to collect other supplemental data, visit project engineers and construction sites, and clarify questions raised during the preliminary analysis of data collected.

Traffic Study Projects

Typical Data Collection Procedures

It was initially anticipated that there would be sufficient overall candidate construction study projects in each State that would permit the selection of field traffic study sites and data collection at 20 sites within the construction study projects in 2 to 5 of the participating States. However, because of the difficulty in locating work zone sites where congestion was experienced within the 50 construction study projects, a search was conducted to select traffic study sites within construction projects in other non-participating States to collect the necessary data.

After the research project principal engineers were assured by a highway agency that congestion would occur at construction sites on four-lane divided highways in rural areas in a State, arrangements were made by telephone to collect data at a specific construction work zone site. Arrangements were made for the highway agency to collect the data, where possible. At sites where data were collected by the researchers, 2 to 5 people, generally college engineering students, were hired to collect the data at each site. One of the principal research engineers generally would then travel to the State to (1) obtain construction plans and inspect the construction site; (2) identify agency sources for field study personnel; (3) meet with the highway agency to discuss the study and finalize data collection support arrangements with the agency; (4) take photographs of the site and the traffic control devices; (5) meet with the field study personnel; and 6) supervise at least the first study period.

A few weeks before a field study, copies of field study procedures and data collection forms were mailed to the study team for their review and study. Copies of general information for field data collection, field study procedures and data collection forms are presented in appendix B for the following types of studies:

(1) Weekday peak periods - SLC;
(2) Weekday peak periods - TLTWO;
(3) Weekday off-peak periods - SLC;
(4) Weekend - SLC;
(5) Weekend - TLTWO;
(6) Holiday weekend - TLTWO.

V. ANALYSIS OF DATA

A total of 51 construction projects in 11 States were analyzed for 7 different types of construction for the TLTWO and SLC traffic control strategies. A listing of each project by type of construction and pertinent features is contained in appendix A. Accident data for each overall study project for the before construction period were compared with accidents during construction. Field traffic studies to measure delay through the work zones were performed at 25 construction sites in 10 different States. The data collected from the 51 construction study projects and traffic study projects in other States were analyzed as the basis of this research study.

Construction Costs

A detailed review was made of the 51 construction projects, and the primary construction work performed in all projects involved improvements to the highway or bridge pavement. All projects were classified in one of 7 general construction type classifications. However, it can be concluded from the analysis performed that no projects within any one classification type of construction contained a similar scope of work in the construction improvements performed within the projects. Even the study projects involving routine pavement maintenance work, such as asphalt concrete pavement overlay (resurfacing) projects, included minor variations in scope of work that preclude direct comparisons for the SLC and TLTWO traffic control alternative methods for handling traffic.

Most highway agencies specified many other items of work within the construction plans for these construction improvement projects, including joint repairs, shoulder repairs or reconstruction, bridge deck overlays, safety upgrading, signing, permanent pavement markings, landscaping or other required improvements to upgrade the highway to current standards. Therefore, it is important to emphasize that the results of direct comparisons of construction costs for specific projects contained in this research study should be used very carefully, and desirably after reviewing the actual details of the construction projects compared. The analysis of construction costs for this research will provide general conclusions with qualifications as can be determined from the knowledge gained in the review of projects as permitted within the time constraints of the research study.

A summary of the construction costs for all projects by type of construction including type of traffic control, alternate TCP analysis estimates and percent of construction costs is shown in table 9.

Table 9. Construction study projects and costs.

Project Number		Route	Project Length (miles)	ADT	Const. Period	Type TCP Used	Primary Chan. Device	Total Const. Cost ($)	TCP Const. Cost ($)	TCP % of Total	Estimated Alternate TCP Cost($)	Alt. TCP % of Total	Alt. TCP Chan. Device	Comments
(A) Concrete Pavement Recycling / Overlay (6 Projects)														
CA	A1	IR-80	6.50	21,600	1988-89	SLC	Tubes	13,295,635	1,142,300	8.59	1,224,569	9.21	AC Div.	4LTWO Alt. = $1,387,490.
MI	A2	IR-94	5.80	29,000	1986	TLTWO	AC Div.	7,968,964	892,065	11.19	1,252,960	15.72	TCB	
OR	A1	IR-5	7.04	24,200	1984-86	TLTWO	TCB	12,012,163	829,722	6.91	No Alternate	—	—	
OR	A2	IR-5 NB	13.18	22,550	1985-87	TLTWO	TCB	9,940,549	366,308	3.68	No Alternate	—	—	
UT	A4	IR-15	8.77	5,218	1985-86	TLTWO	TCB	11,640,004	1,234,783	10.61	1,206,928	10.37	Drums	
UT	A5	IR-80	4.87	12,860	1985-86	TLTWO	TCB	11,570,513	1,195,715	10.33	No Alternate	—	—	Raise Highway Grade
AVERAGES:			7.69	19,238				11,071,305	943,482	8.56				
(B) Concrete Pavement Restoration (5 Projects)														
LA	B14	IR-20	5.65	23,470	1987	SLC	Cone/Dr ?	699,782	15,000	2.14	585,988	83.74	AC Div.	
NC	B7	IR-40	5.82	35,000	1984-85	SLC	Drums	4,056,619	235,927	5.82	706,029	17.40	AC Div.	Iowa Weave TCP
NC	B8	IR-95	10.05	20,000	1984-86	SLC	Drums	4,901,963	216,345	4.41	1,166,218	23.79	AC Div.	Iowa Weave TCP
OH	B1	IR-75	5.02	25,358	1987	SLC	Drums	3,615,648	299,935	8.30	562,795	15.57	AC Div.	
OR	B4	IR-5	15.52	20,550	1986-87	SLC	TCB	9,186,768	562,754	6.13	947,598	10.31	TCB	
AVERAGES:			8.41	24,876				4,492,160	265,992	5.36				
(C) Asphalt Concrete Pavement Overlay (13 Projects)														
AZ	C5	IR-8	5.13	5,900	1986	SLC	TCB	2,222,615	247,029	11.11	311,200	14.00	TCB	
AZ	C11	IR-10	12.10	8,000	1987-88	SLC	Cone/Dr ?	3,011,793	75,711	2.51	583,600	19.38	TCB	
FL	C15	IR-295	4.77	20,000	1986-87	SLC	Cone/Dr ?	1,865,670	137,851	7.39	580,158	31.10	AC Div.	
FL	C16	IR-295	7.52	26,000	1987-88	SLC	Cone/Dr ?	2,466,210	160,599	6.51	747,453	30.31	AC Div.	
KY	C4	SR-114	12.50	7,590	1985-86	SLC	Cone/Dr ?	7,602,570	199,094	2.62	318,952	4.20	Tubes	
LA	C3	IR-10	8.96	24,070	1986-87	SLC	Drums	3,588,713	52,500	1.46	831,385	23.17	AC Div.	
LA	C4	IR-12	12.86	21,610	1986	SLC	Drums	1,294,622	35,000	2.70	689,840	53.29	Tubes	
MI	C10	IR-96	5.88	24,500	1986-87	SLC	Drums	1,643,603	38,042	2.31	449,405	27.34	AC Div.	
NC	C3	IR-85	6.00	30,000	1987-88	SLC	Drums	3,437,750	356,388	10.37	759,445	22.09	AC Div.	Iowa Weave TCP
NC	C17	IR-85	11.82	41,300	1985-86	SLC	Drums	2,607,689	155,501	5.96	1,471,519	56.43	AC Div.	
OR	C6	IR-84	18.39	5,550	1986	SLC	TCB	6,824,651	568,358	8.33	972,454	14.25	TCB	
OR	C8	IR-84	16.89	12,425	1987	SLC	Cones	366,192	13,370	3.65	628,430	171.61	TCB	
UT	C3	IR-15	15.34	4,543	1987	SLC	Drums	2,813,652	82,641	2.94	652,340	23.18	Drums	
AVERAGES:			10.63	17,807				3,057,364	163,237	5.22				
(D) Bridge Deck Overlay (4 Projects)														
KY	D7	IR-75	0.22	26,000	1986-87	SLC	Cone/Dr ?	493,862	19,500	3.95	219,055	44.36	Tubes	
MI	D5	IR-196	0.08	11,400	1986	SLC	TCB	520,432	122,408	23.52	497,757	95.64	AC Div.	
WV	D3	IR-64	0.69	19,000	1986	SLC	Drums	174,585	19,978	11.44	262,500	150.36	AC Div.	
WV	D8	IR-79	0.16	6,200	1986-87	SLC	TCB	1,220,779	18,417	1.51	473,465	38.78	AC Div.	
AVERAGES:			0.29	15,650				602,414	45,076	10.11				

Legend

AC Div. = Asphalt Concrete Divider
TCB = Temporary Concrete Barrier
Mov. TCB = MovableTemporary Concrete Barrier
C.O. = Change Order

Table 9. Construction study projects and costs. (continued).

Project Number		Route	Project Length (miles)	ADT	Const. Period	Type TCP Used	Primary Chan. Device	Total Const. Cost ($)	TCP Const. Cost ($)	TCP % of Total	Estimated Alternate TCP Cost($)	Alt. TCP % of Total	Alt. TCP Chan. Device	Comments
(E) Bridge Deck Replacement / Widening (6 Projects)														
AZ	E2	IR-40	4.19	8,800	1986-87	SLC	TCB	2,558,259	253,094	9.89	827,210	32.33	TCB	Bid TLTWO; SLC per C.O.
AZ	E6	IR-10	0.20	12,000	1986-87	TLTWO	TCB	1,681,428	357,135	21.24	No Alternate	—	—	
LA	E1	US-190	1.19	16,000	1986-89	TLTWO	Tubes	15,020,322	544,540	3.63	No Alternate	—	—	Incomplete Final Costs
NC	E9	US-1 SB	0.10	15,000	1985-87	TLTWO	AC Div.	879,999	71,368	8.11	103,000	11.70	N/A	Design Alternate TCP Estimated Costs
WV	E5	IR-64	0.89	27,000	1987-89	TLTWO	TCB	2,567,684	709,449	27.63	No Alternate	—	—	Incomplete Final Costs
WV	E6	IR-77	0.60	9,300	1986-87	TLTWO	TCB	1,041,904	315,922	30.32	No Alternate	—	—	
AVERAGES:			1.20	14,683				3,958,266	375,251	16.80				
(F) Reconstruction (11 Projects)														
KY	F9	WKP	1.70	4,200	1986-87	TLTWO	Tubes	1,364,803	172,161	12.61	No Alternate	—	—	Existing TLTWO/Landslide Repair
LA	F6	IR-59	5.54	12,980	1986-88	TLTWO	Tubes	10,649,517	900,438	8.46	No Alternate	—	—	Incomplete Final Costs
LA	F7	IR-20	2.68	27,590	1986-87	TLTWO	Tubes	5,048,848	698,387	13.83	No Alternate	—	—	
LA	F9	IR-20	6.78	13,530	1985-87	TLTWO	AC Div.	10,111,189	887,875	8.78	No Alternate	—	—	
LA	F15	IR-20	7.21	23,870	1985-88	TLTWO	Tubes	11,947,245	1,040,073	8.71	876,780	7.34	Drums	
MI	F6	IR-96	8.20	12,800	1987	TLTWO	AC Div.	8,304,603	394,681	4.75	918,630	11.06	TCB	
MI	F8	IR-94	5.97	18,500	1987-88	TLTWO	AC Div.	7,638,414	406,969	5.33	1,588,884	20.80	TCB	
NC	F1	IR-40	18.43	15,000	1984-87	SLC	Drums	9,135,648	977,682	10.70	1,516,804	16.60	AC Div.	
NC	F2	IR-40	14.23	25,000	1985-88	TLTWO	TCB	9,523,144	934,015	9.81	1,197,550	12.58	Mov. TCB	
NC	F4	IR-40	8.96	17.000	1988-89	TLTWO	AC Div.	6,416,317	1,112,589	17.34	1,684,063	26.25	Mov. TCB	Incomplete Final Costs
NC	F5	IR-77	9.23	32,000	1987-89	SLC	Mov. TCB	5,472,109	1,302,858	23.81	1,609,404	29.41	AC Div.	TCB Transporter / Incomplete Final Costs
AVERAGES:			8.08	18,406				7,782,894	802,521	11.28				
(G) New / Interchange Construction (6 Projects)														
AZ	G7	IR-10	2.11	33,000	1986-87	SLC	TCB	3,085,206	375,802	12.18	252,400	8.18	TCB	Interchange Construction
FL	G5	SR-95	3.02	4,900	1986-88	TLTWO	Cone/Dr ?	5,610,988	151,636	2.70	No Alternate	—	—	Addition of two lanes
KY	G1	IR-75	0.40	23,000	1987	TLTWO	Cones	2,409,566	122,040	5.06	No Alternate	—	—	Interchange Reconstruction
MI	G3	IR-69	2.02	15,500	1985-88	TLTWO	TCB	15,976,716	296,642	1.86	100,552	0.63	Drums	Bid SLC; TLTWO Per C.O. / Intge Const. on U.S. 127
NC	G13	IR-40	2.70	30,000	1986-88	SLC	TCB	5,892,592	512,974	8.71	1,111,150	18.86	TCB	Partial Interchange Construction
UT	G6	IR-84	14.15	3,845	1983-86	TLTWO	Drums	21,346,357	749,244	3.51	No Alternate	—	—	Addition of two lanes
AVERAGES:			4.07	18,374				9,053,571	368,056	5.67				

Legend

AC Div. = Asphalt Concrete Divider
TCB = Temporary Concrete Barrier
Mov. TCB = MovableTemporary Concrete Barrier
C.O. = Change Order

Types of Construction and Traffic Control Alternatives

The 7 types of construction classifications for the study projects were identified for comparative purposes because of the anticipated construction methods that would likely lend themselves to alternative analysis for handling traffic using either of the two traffic control strategies. The following is an analysis of each construction classification by type.

(1) Type A--Concrete Pavement Recycling/Overlay (6 projects)

Each of these projects involved completely removing and replacing existing Portland cement concrete (PCC) pavement or placing a concrete pavement overlay on an existing pavement surface. All of the projects, with the exception of a project in California, specified use of the TLTWO as the primary method of handling traffic through the work site. The Interstate 80 project in California was included within this study because of the additional flexible options afforded by the avaiability of a full median shoulder for traffic control.

As mentioned previously, the research contractor was advised by State representatives that for this classification of projects no alternate option for a SLC was possible for performing the needed pavement replacement. To obtain more insight concerning traffic control for these projects, input was solicited from the American Concrete Pavement Association (ACPA) which offered comments after contacting several concrete paving contractors, some of whom were involved in the projects, regarding several sample study projects furnished.

Based on the knowledge gained from discussions with State personnel and ACPA, the following reasons were offered for using the TLTWO method for traffic control on these projects:

(a) Removal of existing pavement, particularly reinforced concrete, presents a safety hazard to passing motorists if they are permitted to travel in a lane adjacent to the pavement removal operation. Only a limited lateral buffer space can be provided adjacent to the lane in which the pavement removal is performed. As a result it was reported that contractor insurance rates would be higher for this method of handling traffic because of the potential for claims against the construction contractor.

(b) Placing new concrete pavement can be performed more efficiently with equipment that can place new pavement in both lanes or a lane and a shoulder concurrently in widths of 24 feet or more.

(c) Delivery of materials during the paving operation can be accomplished without interfering with traffic, which would be stopped or delayed during the delivery and departure from the work site. The potential safety conflict between motorists and construction equipment would be reduced.

(d) Traffic passing in an adjacent lane during both pavement removal and placement operations would be unduly slowed or delayed by the distraction (or attraction) of the construction work.

<u>Alternate Traffic Control Analysis</u>

A detailed analysis of traffic control costs and alternate traffic control cost estimates is discussed in a later section of this report. However, with the knowledge of the above information, an alternate analysis was performed to determine the estimated costs for using the SLC strategy for traffic control on these types of construction projects. Since no study projects were constructed using this strategy, except the California I-80 project with full width median shoulders, the following assumptions were made as a basis for the analysis:

(a) A typical roadway cross section of 4 ft. - 24 ft. - 10 ft. (median shoulder - pavement width - right shoulder) was used, assuming shoulders are asphalt concrete.

(b) Pavement removal and placement will reduce the open lane adjacent to traffic to 6 ft. of usable width.

(c) The median shoulder will be paved and temporarily widened from 4 ft. to 8 ft. in order to accommodate traffic in the median lane during work in the right lane.

(d) The right shoulder will be paved with a thin overlay to carry traffic during work in the median lane.

(e) Channelization devices used will be comparable to State policy for typical construction work involved.

The following sequence of construction was used for the analysis:

(a) Widen the median shoulder from 4 ft. to 8 ft., and maintain traffic in the right lane.

(b) Remove the pavement and pave the right lane and shoulder (12 ft. & 10 ft.), traffic maintained in the left lane and median shoulder with a 6 ft. buffer width between travel lanes and work site.

(c) Remove the pavement and pave the left lane and median shoulder (4 ft. & 12 ft.), with traffic maintained in the right lane and shoulder.

A sample alternate analysis and cost estimate for SLC is shown in table 10 for Louisiana Project F15 using temporary concrete barrier for channelization. The cost for traffic control using the alternate SLC in the sample is an estimated $ 376,780 excluding an additional time cost with the alternate method.

Each of the Type A (Concrete Pavement Recycling/Overlay) projects using TLTWO were analyzed for costs and feasibility of construction using the SLC method of traffic control with the results shown in table 9. Several projects (Oregon A1 and A2 and Utah A4) were found to be not feasible to construct with a SLC because of (1) narrow bridges with shoulders that would not permit maintaining a single lane of traffic; (2) SLC would not be economically feasible because of the construction methodology; or (3) additional time to construct, which is estimated to increase construction costs in the range from 10 to 19 percent of the total construction cost.

The one exception to the use of the SLC strategy is the Interstate 80 project in California. Although this study project was identified late during the research study, and no accident data were collected because of time constraints, it has one feature worth noting. It had full width 10 ft. median shoulders, which permitted additional flexibility for traffic control during construction. This construction improvement project is through Donner Pass and carries a high volume of traffic, particularly during the tourist and skiing seasons. The project involved the construction of a concrete pavement unbonded overlay over existing PCC while maintaining two 11 ft. lanes of traffic through the work site.

The additional median shoulder width permitted all construction work, except paving, to be performed while traffic was maintained on a portion of the second directional lane and the median shoulder in two lanes of traffic. Caltrans permitted traffic to be maintained in one lane on the project with a SLC only during paving operations during restricted weekday hours. An alternate analysis was performed for a TLTWO strategy which resulted in an estimated cost slightly higher than the actual project cost. Because of the requirement that four lane traffic be maintained during construction at times other than when paving, the alternate TCP was not actually feasible. An analysis for a 4LTWO strategy was performed which was estimated at a cost approximately $ 250,000 higher than the contract bid as shown in table 9. The cost analysis for this project was based on contract bid prices, as final costs were not available for inclusion with the research study.

While most rural freeways do not have the luxury of a full shoulder in the median, in some cases where high traffic volumes or heavy commercial traffic is encountered, it would appear desirable to provide a full median shoulder for many maintenance or construction operations that could be performed with less

Table 10. Sample alternate analysis and cost estimate for SLC Louisiana project F15.

IR-20-2(060)86 [LOUISIANA #F15]	SHT.	LOCATION	INSTALL	REMOVE	MAINTAIN	REMARKS
Length = 7.207 miles						Two interchanges
PCC Pavement (13" thick), AC Shoulder						STARTED:
and 6" Subbase Treatment Reconst.						COMPLETED:
						DESIGN SPEED = 70 MPH
						Median width = 56'
1. Lane Closures						
a. Shoulder Rehabilitation		Inside Shoulder	$501,840			8,364TONS @ $60/TON
		Outside Shoulder	$302,940			5,049TONS @ $60/TON
b. Const. Channelizing Devices			$30,000			60 EA @ $500/EA (LA avg)
						Temp. Precast Barr.
c. Traffic Control						
i. Removal of Existing Markings						
ii. Pavement Markings/Markers			$10,000			(LA#C3) X 0.80
iii. Const. Signs			$32,000			(LA#C3) X 0.80
						Temp. Signs & Barr.
iv. Flashing Arrow Board						
v. Barricades						
vi. Warning Lights						
d. Pavement Maintenance						
TRAFFIC ALTERNATE TCP COST ESTIMATE:			$876,780	$0	$0	$876,780.00
TOTAL PROJECT COST BID:						$11,987,596.00
TOTAL PROJECT COST ACTUAL:						$11,947,245.00

COMMENTS:
Comparable to LA#C3.

State Project #451-05-59

interference to traffic.

The research finding on traffic control for concrete pavement recycling and overlay construction improvements is that TLTWO was normally utilized to handle traffic during construction.

(2) Type B--Concrete Pavement Restoration (5 projects)

This type of construction improvement project involves the intermittant replacement of concrete pavement sections. As can be seen from table 9 the normal method of traffic control employed was the SLC. This construction may create considerable turbulance to traffic flow, however, particularly during the paving operations. Some of the features described previously occur during this operation. An Ohio project (B1), which was field studied for measuring traffic delay and congestion late during the construction of the project, did not experience traffic delays during the study that were caused by deficinent capacity. However, many delays were reported by the construction project personnel prior to the field study that involved long queues of traffic for as much as 1 or 2 miles in advance of the work site. This was reported to occur on weekends during Friday afternoon peak hours continuing into the evenings and on Sunday afternoons and evenings during the summer.

While observing traffic flow through the work site in preparation for and during one of the field studies, the principal investigator noticed that the paving operation did cause delays and stoppage of traffic. The delays were primarily caused by the concrete trucks entering and leaving the work site where the paving operation was in progress. It is necessary during paving for concrete trucks to mix with the through traffic to deliver concrete to the paver. Trucks must decelerate to a very low speed in the travel lane prior to moving in front of the paver to unload the material. After unloading the material the driver must then move back into the through travel lane from a stopped position, which frequently requires a flagger, depending on availability of suitable gaps to enter the traffic flow. In addition there is the normal "rubber necking" that occurs by passing motorists curious to watch the paving operation. During hours of traffic flow through the work site these two problems often disrupt the normal flow of traffic, although measured traffic volumes do not approach the actual capacity for the work site.

Contractor and project personnel at the Ohio project work site believed that a TLTWO would have greatly simplified their work task and provided a more efficient and safer work site. The experience concerning accident rates for restoration projects will be discussed in the accident analysis section of this report.

As previously mentioned, the SLC strategy was employed for each of the 5 study projects involving concrete pavement restoration. An alternate analysis of the traffic control costs for TLTWO was performed for each of the 5 projects. Table 9 contains the results of these analyses and shows that there is a considerable additional construction cost associated with TLTWO when compared with the SLC strategy specified in each of the construction projects.

Based on the results of the alternate TCP construction cost analyses for pavement restoration projects, the SLC was found to be the most economical means of handling traffic during construction for concrete pavement restoration projects. The sample size of only 5 study projects may not appear to be large enough to substantiate the results of the cost analysis to support this conclusion, but the projects are deemed to be typical.

Field observations during field studies to measure delays through lane closures in this research study, such as the construction of the Ohio project, indicate that the actual construction work itself can cause extensive congestion, even though demand traffic volumes are less than the work zone capacity. For pavement restoration projects where there is an extensive amount of pavement replacement work and high demand traffic volumes and/or truck percentages, there would appear to be valid reasons to consider TLTWO. Further research into comparative costs involving frequency of incidents would have to be performed to verify this.

(3) Type C--Asphalt Concrete Pavement Overlay (13 projects)

The largest sample of study projects furnished for consideration by the States was in this classification. The reason is probably because most State maintenance programs include extensive asphalt concrete (AC) pavement resurfacing as a routine part of annual roadway maintenance activities. The conventional method of handling traffic for these projects is the SLC strategy.

AC overlays are normally placed over existing pavement that is in decent shape structurally, and the overlay work can be performed by placement of the total thickness in several layers (lifts) with several passes by an AC paver to reach the specified thickness of the total overlay required. Maximum lift thickness is governed by the thickness that can be safely traversed by motorists once the pavement has been rolled and channelization devices have been removed. Traffic control must be very portable since the paving operation relocates frequently during each day's operation. One of the more typical problems with this construction operation is maintaining a consistent distance between the stationary advance warning sign system and the paving train. This must be accomplished to maintain signing credibility that work is indeed being performed, and in the interest of traffic safety to maintain appropriate traffic speeds through the work zone for the safety of the workers and protection of the equipment.

One of the most critical traffic control conditions during construction of AC overlay projects occurs when repair or replacement of transverse construction joints must be performed in conjunction with the overlay construction. This type of work was included within several of the study projects. Joint reconstruction requires removal and replacement of pavement adjacent to the transverse joint prior to the placement of the overlay. Lane closures during joint repair usually require more restrictive traffic control measures laterally because of open pavement sections and infringements on traveled way by construction equipment.

A study project in North Carolina (C3) employed the "Iowa Weave" strategy to slow motorists approaching the work site by using alternating channelization that forces traffic to change lanes and desirably slow down before reaching the work site.[9]

An alternate TCP cost analysis was performed on each study project in this classification, and in all cases it was found that the TLTWO alternative was far too costly to consider for these projects, primarily because of the cost to construct median crossovers to implement the TLTWO. Table 9 shows the results of the cost analyses. The SLC strategy was found to be the most cost-effective method for traffic control on study projects that were exclusively AC pavement overlay projects. When extensive joint or shoulder repairs are necessary in conjunction with AC pavement overlay projects, a more detailed analysis of traffic control strategies should be undertaken to determine whether TLTWO is more cost-effective.

(4) Type D--Bridge Deck Overlay (4 projects)

This type of construction improvement project typically consists of installing new latex modified pavement overlays on existing bridge decks without any major widening or bridge parapet repairs or modifications. Work for the 4 projects studied typically included the removal of portions of the bridge deck by jack hammer or other appropriate means as necessary before placing the deck overlay.

SLC was used to handle traffic on all projects studied, and the temporary concrete barriers were used to protect the work site on 2 of the projects. Although the sample size for this study is small, it appears that the projects were very typical of construction work on these type projects.

An alternate TCP cost analysis was performed for each of the four projects and table 9 shows that the TLTWO strategy was much too costly to justify implementation on these projects. The SLC strategy was found to be the most cost-effective traffic control to implement on bridge deck overlay projects.

(5) **Type E--Bridge Deck Replacement/Widening (6 projects)**

This type of bridge improvement project involves more extensive work to the bridge structures as the title implies. Many of the projects studied included extensive roadway work in addition to the structures work. All except 1 of the 6 projects used the TLTWO strategy to handle traffic because of the need for adequate work space on each bridge to perform the major construction improvement work.

As can be seen in table 9, 1 project, Arizona E2, originally specified TLTWO for the bridge work involving deck widening from 30 ft. to approximately 42 ft. (and SLC for the remainder of the roadway work in the project). Traffic control was modified by a change order requested by the construction contractor and approved by the Arizona DOT to use a SLC for the bridge construction work also. Bridge decks were existing prestressed concrete voided slabs to be widened with slabs of similar design. The change order on this project resulted in a significant cost savings of $ 250,000, and specifications in Arizona typically require that the savings be equally shared by the Arizona Depatrtment of Transportation and the contractor. The alternate TCP cost analysis performed for this project assumed TLTWO was used during construction of the entire project. Table 9 shows that the cost (approximately $ 827,210 using Temporary Concrete Barrier throughout) would have been much greater than the savings mentioned above.

An alternate TCP design cost analysis was performed by the States for only two projects prior to construction, both in North Carolina. For 1 of the projects, North Carolina E9, an alternate TCP design analysis was performed by the North Carolina Department of Transportation. The cost of a detour was considered as the only feasible alternative and was estimated to be $ 103,000. When compared to the use of the TLTWO specified, the alternate TCP design estimate proved to be significantly more than the actual construction cost of $ 71,368 as shown in table 9. In all other cases no alternate TCP cost analysis was performed because the existing bridge deck width was too narrow to maintain one lane of traffic, or the bridge was actually replaced.

For these types of projects, except in special cases, such as encountered in Arizona Project E2, the research finding was that the most cost-effective method for handling traffic was the TLTWO. Many of these projects were initiated because the existing bridge decks had to be widened to satisfy current design standards, but not widened to provide for additional lanes.

(6) **Type F--Reconstruction (11 projects)**

These projects were the second largest sample to be studied. They typically involved the most costly and extensive construction improvement work for replacing continuous lengths of pavement and subbase material, and included shoulder replacement in some projects. These projects also included a significant amount of other permanent improvements for safety, such as flattening side slopes and guard rail replacement. As can be seen in table 9, the majority of the projects used TLTWO for handling traffic during construction because of the need for minimal traffic interference with the construction work.

Only 2 of these study projects used the SLC strategy to handle traffic during construction. In both these cases, North Carolina Projects F1 and F5, construction work did not involve continuous pavement replacement, but primarily involved concrete slab replacement (pavement restoration type work), extensive AC pavement milling and overlays, and transverse construction joint repair work.

Project F1 began in 1984 and involved extensive AC milling and overlay. There were significant problems with traffic control (see Appendix) requiring modifications to the TCP. Project F5 primarily involved slab replacement, joint repairs and providing an AC overlay of pavement and shoulders. Project F5 also was the initial State freeway project employing SLC traffic control with the recently developed technique using movable temporary concrete barrier relocated by special transporter equipment. These 2 projects could be considered exceptions to the other 9 projects in this classification.

For the same reasons cited in the analysis of concrete pavement recycling and overlay construction projects, several States indicated that there was no SLC traffic control alternative to the TLTWO for these projects. The researchers also found no possible TCP alternative for several of the projects because of narrow bridges. However, cost analyses were performed using the methodology described in section I of this report for the SLC alternative to verify the cost feasibility. In all but Louisiana project F15, the estimated alternate SLC cost was considerably higher than the actual construction cost.

The alternate cost analyses for each of the 9 study projects also did not consider any change in time to construct the project using the alternate SLC method of traffic control. As previously mentioned in section I, it is not possible to estimate a reasonable change in cost due to change in construction time, but in all cases it is believed that a conservative estimate of time for the SLC strategy would be an increase in the range of 10 to 19 percent additional time and total construction cost. This additional cost would be caused by the interference to construction progress by traffic in a travel lane adjacent to the work area, and would create delay to the contractor in performing his work. The added safety hazard to workers and motorists and probable damage claims would likely increase the contractor's insurance costs. These are all intangible costs, but are judged to be additional to estimated costs for the alternate analysis costs.

It also should be noted that for several study projects final construcion costs were not available, but they would not appear to have any bearing on the overall cost analysis of these projects.

The research finding in analyzing construction costs only for projects studied is that the most cost-effective method for handling traffic for major reconstruction projects with extensive pavement replacement is by using the TLTWO strategy.

(7) Type G--New/Interchange Construction (6 projects)

These study projects were selected to demonstrate the wide variety of projects on which SLC and TLTWO strategies may be employed to handle traffic. The projects in this classification are not comparable to the other 6 category types because of dissimilarities in work performed. However, several of the projects in this category demonstrate interesting examples of how the 2 traffic control strategies have been used to solve traffic control problems.

Both the Florida G5 and Utah G6 projects involved new construction where a pair of new lanes were constructed adjacent an existing two-lane highway to develop a four-lane divided highway. Construction of the Florida G5 project resulted in a four-lane divided highway and partially a five lane undivided highway. TLTWO was maintained on the existing pair of lanes while the new roadways were constructed; then traffic was shifted onto the new pair of lanes until the existing pair of lanes was improved for use of the entire highway facility. No alternate TCP cost analysis was performed for either project because of the nature of the projects.

The Arizona G7 project was an interchange construction project on Interstate 10 southeast of Tucson in which several complementary ramps were constructed for an existing interchange to provide a complete interchange with all movements. The project was one of the 3 construction study projects for which field traffic studies were performed to measure traffic delay through the work site. The project carried a two-way ADT of 33,000, and the field study provided significant data to assist in developing traffic volumes for establishing capacity threshold levels for lane closures through work zones. This project experienced one of the highest peak hourly volumes through the work site without experiencing delay to through traffic. See the field studies analysis section of this report for data and analysis.

The Kentucky G1 project was an interchange reconstruction project where two interchanges were modified to handle traffic for a new automobile manufacturing plant. The unique feature to this construction on Interstate 75 north of Lexington was the use of

TLTWO which was installed and removed daily during construction while the existing interchange bridge overpass was widened to accommodate additional traffic demand. Median crossovers were constructed prior to the interchange reconstruction contract letting to minimize time for the project. The TLTWO was placed in operation on weekdays during daytime off-peak hours using cones for channelization. Figure 7 shows a picture of the operation.

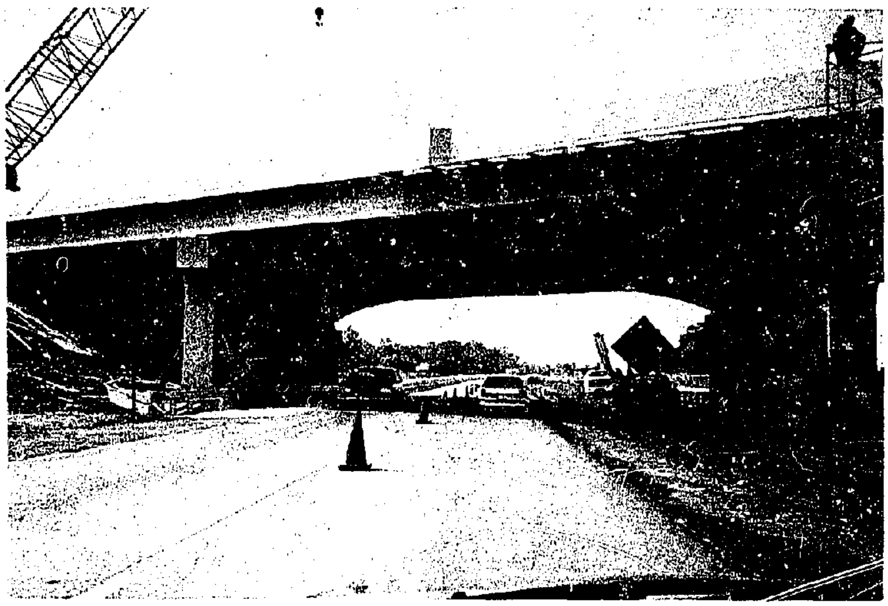

Figure 7. Temporary TLTWO with cones on I-75 in Kentucky.

The Michigan G7 project involved new construction for Interstate 69 northeast of Lansing in which a new interchange was constructed for U.S. 127. TLTWO was used to handle traffic on U.S. 127 during interchange construction as a result of a change order request by the contractor. A SLC was specified on US 127 in the original construction plans, but the contractor proposed the TLTWO based on his desire to save time in the interchange construction work. The change order was approved at no additional cost to the State and required the use of temporary concrete barrier for the separation of traffic flow.

The research study did not find any consensus on traffic control strategy for this type of construction project because of the dissimilarities in the scope of work involved in each project. No alternate TCP analyses were performed for these projects.

Traffic Control Cost Analysis

Each State was contacted during the preliminary phase of the research study to obtain standard construction specifications, special provisions, recent bid prices and other data to determine the unit prices used for bidding traffic control elements of the construction projects. A summary of each State's known policies based on a summary furnished by FHWA to the researchers was forwarded to each State for confirmation and accuracy.

It was found that there was a wide variation in State practices, although all States were either using unit prices for bidding traffic control items or phasing some form of unit prices into their bidding practices. During the cost analysis phase of each of the construction study projects, further variations of basis of payment were obtained from the construction plans, bid tabulations and other bidding documents. For a number of the study projects construction had been completed where some States had used lump sum prices for traffic control. A summary of bid items and bases of payment for each of the 51 study projects is contained in table 11. Note the wide variation in bidding methods.

An analysis was made of the costs for traffic control bid items in order to develop a range of costs for the various bid items. Table 12 shows the typical bid items with the range of costs in the construction study projects within the State and the basis of payment. Two States, Michigan and West Virginia, specified unit prices for all traffic control; Ohio specified lump sum for nearly all traffic control work except for temporary markings; eight other States specified unit prices for some work items and included the remaining work in a maintenance of traffic lump sum item. Utah and Louisiana specified traffic maintenance work to be included within a lump sum mobilization bid item.

California specified a separate lump sum item for furnishing and installing traffic control devices and a separate lump sum item for maintenance of the devices. West Virginia specified unit values for signs, barricades, drums, cones, etc. in a traffic control devices rate schedule ranging in value from 0 to 100 points per each type device. An estimated total unit quantity was provided in the contract documents, which was then paid for on a unit price per actual number of units used and accepted. One study project in Arizona specified unit prices with estimated quantities for all potential contractors to use in bidding on the work. It is now standard practice for the Arizona Department of Transportation to develop and provide an engineer's estimate of unit prices and cost to prospective bidders as the basis of payment for traffic control to be used by all contractors bidding on a project.

The basis of payment for many common bid items also varied

Table 11. Basis of payment by State and project.

STATE:	AZ	AZ	AZ	AZ	AZ	CA	FL	FL	FL	KY	KY	KY	KY	LA	LA	LA	LA	LA	LA	LA	LA	MI	MI	MI	MI	MI
PROJECT:	C5	C11	E2	E6	G7	A1	C15	C16	G5	C4	D7	F9	G1	B14	C3	C4	E1	F15	F6	F7	F9	A2	C10	D5	F6	F8
YEAR BID:	86	87	86	86	86	88	86	87	86	85	86	86	87	87	86	86	86	85	86	86	85	86	86	86	87	87
ITEM BID:																										
Advance Warning Arrow Panel	HR		HR	HR	HR		E/D	E/D	E/D	EA		EA	EA								EA	EA	EA	EA	EA	EA
Asphalt Concrete Divider																					LF	LF			LF	LF
Attenuator						EA											(4)	EA	EA	EA	EA					
Attenuator Replacement Parts																										
Barricades				E/D			E/D	E/D	E/D													EA	EA	EA	EA	EA
Construction Signs				E/D			E/D	E/D	E/D													SF	SF	SF	SF	SF
Delineators				EA																						
Flagging																						LS	LS		LS	LS
Flagging (Force Account)	LS		LS	LS	LS																					
Flexible Post Markers																	EA	EA	EA	EA	EA	EA			EA	EA
Maintenance of Traffic	LS	LS	LS		LS	(1)	LS	LS	LS	LS	LS	LS	LS	(3)												
Minor Traffic Devices																						LS	LS	LS	LS	LS
Non-Metalic Drums																										
Portable Traffic Control Devices																										
Remove Pavement Markings	LF			LF																		LF		LF	LF	LF
Temporary Signs & Barricades															LS	LS	LS	LS	LS	LS	LS					
Temporary Concrete Barrier	LF		LF	LF	LF	LF							LF				EA	EA	(5)	(5)	EA			LF		LF
Temporary Pavement Markers						EA				EA							EA	EA	EA	EA					EA	EA
Temporary Pavement Markings	LF			LF		LF	(2)	(2)	(2)						LS	LS	LS	LF	LS	LS	LS	LF			LF	LF
Temporary Pavement Markings (Tape)					LF							LF										LF	LF	LF	LF	LF
Tubular Markers												EA														

Key - Special Bid Items

(1) - "Traffic Control System" @ LS and "Traffic Control Surveillance" @ LS.
(2) - "Temporary Pavement Markings (Skip)" @ Gross Mile
and "Temporary Pavement Markings (Solid)" @ Net Mile.
(3) - "Mobilization, Temporary Signing and Barricades" @ LS.
(4) - "Impact Attenuators, DOTD Owned" @ Each.
(5) - "Temporary Precast Barr. (DOTD)" @ Each and "Temporary Precast
Barr. (15')" @ Each.

Legend

E/D = per Each per Day
EA = per Each
HR = per Hour
LF = per Linear Foot
Lf/D = per Linear Foot per Day
LS = per Lump Sum
Mi = per Mile
SF = per Square Foot
Sf/D = per Square Foot per Day

Table 11. Basis of payment by State and project. (continued).

STATE:	MI	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	OH	OR	OR	OR	OR	OR	UT	UT	UT	UT	WV	WV	WV	WV
PROJECT:	G3	B7	B8	C3	C17	E9	F1	F2	F4	F5	G13	B1	A1	A2	B4	C6	C8	A4	A5	C3	G6	D3	D8	E5	E6
YEAR BID:	85	84	84	87	85	85	84	85	88	87	86	87	84	85	86	86	87	85	85	87	83	86	86	87	86
ITEM BID:																									
Advance Warning Arrow Panel	EA	EA	EA	EA	EA	EA	EA	EA	EA	EA	EA		EA	EA	EA	EA	EA	HR	HR	HR	HR	E/D	E/D	E/D	E/D
Asphalt Concrete Divider						LF			LF																
Attenuator		EA	EA	EA			EA	EA		EA	EA				EA				EA		EA	(11)			
Attenuator Replacement Parts		EA	EA	EA			EA	EA		EA	EA								EA		EA				
Barricades	EA		LF		LF	LF		LF	LF		LF		EA	EA	EA	EA	EA			Lf/D					
Construction Signs	SF	SF	SF	SF	SF	SF	SF	SF	(6)	SF	(6)		SF	SF	SF	SF	SF	(8)		Sf/D	(8)				
Delineators			EA				EA	EA		EA			EA	EA							EA				
Flagging	LS											(7)	HR	HR	HR	HR	HR	HR	HR	HR	HR	HR		HR	HR
Flagging (Force Account)																									
Flexible Post Markers																									
Maintenance of Traffic												LS	LS	LS	LS	LS	LS								
Minor Traffic Devices	LS																					(10)	(10)	(10)	(10)
Non-Metalic Drums		EA	EA	EA	EA	EA	EA	EA	EA	EA	EA										(9)				
Portable Traffic Control Devices		LS	LS	LS	LS	LS	LS	LS	LS	LS	LS														
Remove Pavement Markings	LF	LF				LF	LF	LF	LF		LF		LF	LF	LF			LF	LF				LF	LF	LF
Temporary Signs & Barricades																									
Temporary Concrete Barrier		LF	LF				LF	LF		LF	LF	LF	LF	LF	LF	LF		LF	LF		LF		LF	LF	LF
Temporary Pavement Markers											EA													EA	
Temporary Pavement Markings	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	LF	Mi	LF	LF				LF	LF	LF	LF	LF		LF	LF
Temporary Pavement Markings (Tape)	LF	LF	LF	LF		LF	LF	LF	LF		LF				LF				LF				LF		
Tubular Markers																									

Key - Special Bid Items (Continued)
(6) - "Stationary Construction Signs" @ SF and "State Furnished Signs" @ SF.
(7) - "Law Enforcement Officer w/Car" @ Hour
(8) - Construction Signs bid both by Each and Square Foot.
(9) - "55 Gal Plastic Drums" @ Each and "Maintenance of Drums" @ LS.
(10) - "Traffic Control Devices" @ Unit and "Cleaning Individual Traffic Control Devices" @ Each.
(11) - "Shadow Vehicle" @ Each / Day.

Legend
E/D = per Each per Day
EA = per Each
HR = per Hour
LF = per Linear Foot
Lf/D = per Linear Foot per Day
LS = per Lump Sum
Mi = per Mile
SF = per Square Foot
Sf/D = per Square Foot per Day

Table 12. Bid item / unit comparison by State.

BID ITEM:	MAINTENANCE OF TRAFFIC		
STATE:	BID ITEM DESCRIPTION:	BID UNIT:	BID PRICES:
ARIZONA	Maintain and Protect Traffic	Lump Sum	$10,000 to $28,600
CALIFORNIA	Traffic Control System	Lump Sum	$150,000
FLORIDA	Maintenance of Traffic	Lump Sum	$40,000 to $94,095
KENTUCKY	Maintain and Control Traffic	Lump Sum	$19,500 to $138,687
LOUISIANA	Mobilization,Temp. Sign & Barr.	Lump Sum	$15,000
MICHIGAN			not bid on projects reviewed
NORTH CAROLINA			not bid on projects reviewed
OHIO	Maintaining Traffic	Lump Sum	$200,000
OREGON	Temp. Protec. & Direc. of Traf.	Lump Sum	$8,000 to $80,000
UTAH	*		* included in "Mobilization"
WEST VIRGINIA			not bid on projects reviewed

BID ITEM:	TEMPORARY SIGNING		
STATE:	BID ITEM DESCRIPTION:	BID UNIT:	BID PRICES:
ARIZONA	Hi/Std Inten'y Sm/Md/Lg Signs	Each / Day	$0.60 to $2.00
CALIFORNIA	Traffic Control System	Lump Sum	$160,000
FLORIDA	Construction Signs	Each / Day	$0.42 to $1.35
KENTUCKY			Incidental to Maint. Traf.
LOUISIANA	Temporary Signs & Barricades	Lump Sum	$25,000 to $200,000
MICHIGAN	Sign Type A (B) Temporary	Square Foot	$2.00 to $9.70
NORTH CAROLINA	Stationary Construction Signs	Square Foot	$5.95 to $10.00
OHIO			Incidental to Maint. Traf.
OREGON	Temporary Signs	Lump Sum	$4.00 to $25.00
UTAH	(Size) Type C-(Number) Signs	Each or Sq.Ft.	$0.27/SF/DY to $16.50/SF
WEST VIRGINIA	Traffic Control Devices	per Unit	$0.01 to $1.90

BID ITEM:	ADVANCE WARNING ARROW PANEL		
STATE:	BID ITEM DESCRIPTION:	BID UNIT:	BID PRICES:
ARIZONA	Flashing Arrow Panel	per Hour	$5.00
CALIFORNIA	Temp. Flasher & Sign Illumin'n	Lump Sum	$10,000
FLORIDA	Flashing Arrow Board (Temp.)	Each / Day	$26.25 TO $30.00
KENTUCKY	Flashing Arrow	Each	$4,000 TO $8,000
LOUISIANA	Flashing Arrow Sign	Each	$15,500
MICHIGAN	Lighted Arrow Type A, Furn'ed	Each	$1,300 TO $5,000
NORTH CAROLINA	Flashing Arrow Panels, Type C	Each	$3,000 TO $6,500
OHIO			Incidental to Maint. of Traffic
OREGON	Sequential Arrow Signs	Each	$100 TO $5,000
UTAH	Adv. Warn. Device "A", Stat'ry	per Hour	$10.00
WEST VIRGINIA	Electric Arrow	per Day	$0.01 TO $35.00

BID ITEM:	TEMPORARY PAVEMENT MARKINGS		
STATE:	BID ITEM DESCRIPTION:	BID UNIT:	BID PRICES:
ARIZONA	Temp. Pavement Markings	Linear Foot	$0.40 to $1.50
CALIFORNIA	Temp. Traffic Stripe	Linear Foot	$1.10
FLORIDA	Temp. Pav't Mrkg (Skip)	Gross Mile	$336.00 to $350.00
KENTUCKY	Removable Lane Tape	Linear Foot	$1.70
LOUISIANA	Temp. Pavement Markings	Lump Sum	$10,000 to $200,000
MICHIGAN	Temp. Pav't Mrkg Type R (NR)	Linear Foot	$0.50 to $2.00
NORTH CAROLINA	Pav't Mrkgs X" W(Y) Paint	Linear Foot	$0.14 to $2.15
OHIO	Temp. Lane (Edge) Line	Mile	$3,076.00
OREGON	Temporary Striping	Linear Foot	$0.05 to $0.20
UTAH	Temporary Traffic Striping	Linear Foot	$0.10 to $1.00
WEST VIRGINIA	Edge(Lane)Line, White(Yellow)	Linear Foot	$0.01 to $300

BID ITEM:	TEMPORARY CONCRETE BARRIER		
STATE:	BID ITEM DESCRIPTION:	BID UNIT:	BID PRICES:
ARIZONA	Temp. Concrete Barrier	Linear Foot	$10.00 TO $15.00
CALIFORNIA	Temp. Railing (Type K)	Linear Foot	$13.00
FLORIDA			not bid on projects reviewed
KENTUCKY	Conc. Barr. Type 12L Temp.	Linear Foot	$28.00
LOUISIANA	Temp. Precast Barr. (15')	Each	$30.00 TO $750.00
MICHIGAN	Temp. Concrete Barrier	Linear Foot	$15.00 TO $26.00
NORTH CAROLINA	Temp. Conc. Median Barr.	Linear Foot	$17.00 TO $70.00
OHIO	Temp. Concrete Barrier	Linear Foot	$12.00
OREGON	Temp. Conc. Barr. Reflectorized	Linear Foot	$8.01 TO $15.00
UTAH	Temp. Precast Conc. Barr.	Linear Foot	$15.00 TO $20.00
WEST VIRGINIA	Temp. Concrete Barrier	Linear Foot	$4.50 TO $12.00

BID ITEM:	BITUMINOUS CONCRETE DIVIDER		
STATE:	BID ITEM DESCRIPTION:	BID UNIT:	BID PRICES:
ARIZONA			not bid on projects reviewed
CALIFORNIA			not bid on projects reviewed
FLORIDA			not bid on projects reviewed
KENTUCKY			not bid on projects reviewed
LOUISIANA	Temp Asphalt Traffic Delineator	Linear Foot	$3.15
MICHIGAN	Bituminous Concrete Curb	Linear Foot	$1.40 TO $1.60
NORTH CAROLINA	Temp Raised Asphalt Island	Linear Foot	$3.60 TO $6.00
OHIO			not bid on projects reviewed
OREGON			not bid on projects reviewed
UTAH			not bid on projects reviewed
WEST VIRGINIA			not bid on projects reviewed

BID ITEM:	FLAGGING		
STATE:	BID ITEM DESCRIPTION:	BID UNIT:	BID PRICES:
ARIZONA	Flagging Service (Force Acct)	Lump Sum	$10,000 to $30,000
CALIFORNIA			Incidental to Maint. Traf.
FLORIDA			Incidental to Maint. Traf.
KENTUCKY			Incidental to Maint. Traf.
LOUISIANA			Incidental to Maint. Traf.
MICHIGAN	Flag Control	Lump Sum	$1,000 to $10,000
NORTH CAROLINA			not bid on projects reviewed
OHIO			Incidental to Maint. Traf.
OREGON	Flaggers	Hour	$1.00 to $30.00
UTAH	Flagging	Hour	$7.50 to $13.50
WEST VIRGINIA	Flaggers	Hour	$10.00 to $30.00

BID ITEM:	IMPACT / CRASH ATTENUATORS		
STATE:	BID ITEM DESCRIPTION:	BID UNIT:	BID PRICES:
ARIZONA			not bid on projects reviewed
CALIFORNIA	Temp. Crash Cushion Module	Each	$240
FLORIDA			not bid on projects reviewed
KENTUCKY			not bid on projects reviewed
LOUISIANA	Portable Impact Attenuators	Each	$15,000 TO $28,000
MICHIGAN			not bid on projects reviewed
NORTH CAROLINA	Stationary Temp. Crash Cushion	Each	$8,500 TO $13,500
OHIO			not bid on projects reviewed
OREGON	Temp. Impact Barriers	Each	$5,000
UTAH	Impact Attenuator Type "A"	Each	$250 TO $15,000
WEST VIRGINIA			not bid on projects reviewed

BID ITEM:	UNIQUE TRAFFIC CONTROL PLAN BID ITEMS		
STATE:	BID ITEM DESCRIPTION:	BID UNIT:	BID PRICES:
ARIZONA	Sign Stand (Large/Small)	Each / Day	$0.80 TO $1.00
CALIFORNIA	Traffic Control System	Lump Sum	$160,000
CALIFORNIA	Traffic Control Surveillance	Lump Sum	$150,000
FLORIDA	High Intensity Flashing Lights	Each / Day	$1.59 TO $2.36
KENTUCKY			
LOUISIANA	Ceramic Road Markers	Each	$16.20 TO $21.00
LOUISIANA	Temp. Signs & Barricades	Lump Sum	$25,000 TO $200,000
LOUISIANA	Mobilization,Temp.Signs&Barr.	Lump Sum	$15,000
MICHIGAN	Minor Traffic Devices (Cones)	Lump Sum	$1,500 TO $35,000
MICHIGAN	Reflectometer	Each	$27,000
NORTH CAROLINA	Transport Vehicle (for TCB)	Each	$185,000
NORTH CAROLINA	Trailer Mtd Var. Message Sign	Each	$28,000 TO $60,000
NORTH CAROLINA	Temp. Loop Detect.	Each	$3,000
OHIO	Law Enforcement Officer w/Car	Hour	$25.00
OREGON	Temporary Illumination	Lump Sum	$60,000 TO $85,000
UTAH	Painted Pavement Message	Each	$75.00 TO $100.00
UTAH	Maintenance of Drums	Lump Sum	$25,000
WEST VIRGINIA	Shadow Vehicle	Day	$150.00
WEST VIRGINIA	Cleaning of Traf. Cont. Devices	Each	$0.01 TO $130.00

by State and included different elements of work. For example, 2 States (Arizona and Florida) require bid items of work per each per day for signs, barricades, drums, etc., while others bid temporary signs per square foot. Some States bid temporary concrete barrier furnished and installed per linear foot, and provide separate payment for relocating the barrier per linear foot.

In addition the TLTWO method of traffic control involves not only installation, maintenance and removal of traffic control devices, but also many roadway items associated with construction of median crossovers, including detour pavement, subbase, embankment, drainage culverts, guard rail and other items. Costs for this work are discussed in the following section of this report.

Median Crossover Costs

This item of construction work is typically associated with the TLTWO method of maintaining traffic on four-lane divided highways, when traffic is shifted onto one pair of lanes while the necessary construction work is performed on the closed lanes. During the study of the 51 projects it was necessary to determine the costs for median crossovers as part of the traffic control cost for TLTWO.

Because a number of ~~roadway~~ work items are included in the cost of median crossovers, it was necessary to determine the costs and include these in the alternate TCP analysis for each construction project as applicable. Many median crossovers were constructed separately from the study projects for which they were used. It was found desirable to compile a summary of the various design, construction cost and other features for each crossover by one way and two way type of construction for each TLTWO project.

The following is an example of the variation in pavement design in 2 different States for median crossovers to demonstrate the problem of developing uniform costs for alternate TCP cost analysis of SLC and TLTWO strategies:

	Crossover 1 (LA F7)	Crossover 2 (OR A1)
Pavement	1 1/2" AC	3" AC
	4" AC	
	3 1/2" AC Base	
	9"	3"
Base	8 1/2" Cr. Stone	12" Aggregate
Total Depth	17 1/2"	15"
Basis Payment:	Per linear foot of temporary road including tamped embankment	Per ton of AC and aggregate base excluding embankment (incidental to other items)

Tables 13 and 14 show a summary of the crossovers constructed for or within most of the study projects where TLTWO was used for traffic control, including features and costs. In the tables a one way crossover is considered to be one-directional lane. A two way crossover is defined as one having an "X" traffic pattern across the median for one-directional use by switching traffic to and from either side of the freeway in various stages of construction.

Range of Costs for Traffic Control

Because of the many work items and the wide variation of basis of payment for each, it was very difficult to develop the actual traffic control cost for construction of the 51 projects studied, as well as estimated ranges of unit prices as required in the final research report. Many items of work involved detailed research of the applicable edition of a State's standard specifications, contract special provisions, bid tabulations and construction plans just to determine a source for costs and work included with the costs of traffic control for construction of each project.

Based on the analysis performed, and other examples similar to the above on median crossovers, it was not possible to find sufficient uniformity among the States to develop unit price ranges for all items of work that could uniformly apply on a national basis. The research study has quantified as many definable costs for traffic control by ranges in the percentage of cost for traffic control as related to the total cost for construction for the various comparative types of construction projects. These relationships are presented in table 9.

A range of costs for each type of construction is presented in the averages shown at the bottom for each type of construction. It can be seen that the range in cost relationships for traffic control is dependent on the type of construction.

(1) In most cases the range in traffic control cost percentages is greater and highest for bridge construction projects (types D and E.)

(2) The range is 1.51 to 23.52 percent for bridge deck overlays and 3.63 to 30.32 percent for bridge deck replacement/widening projects. This is primarily because of the short lengths of highway involved for relatively minor bridge work, and the use of TLTWO for traffic control with median crossovers and/or the need for positive barriers to separate motorists from workers.

(3) Traffic control costs relationships for the concrete pavement recycling/overlay and reconstruction projects (types A and F) also were relatively high (3.68 to 11.19 and 4.75 to 23.81

Table 13. TLTWO median crossover features and costs (one way).

Project Number		Route	Project Length (miles)	ADT	Primary Chan. Device	Degree of Curve	Median Width (feet)	Pavt. & Shldr. Width (feet)	X-over Length (feet)	Crossover Cost ($)
OR	A1	IR-5	7.04	24,200	TCB	4	76	20	712	18,877
OR	A2	IR-5 NB	13.18	22,550	TCB	4	64	20	579	16,389
UT	A4	IR-15	8.77	5,218	TCB	1.5	58	20	1,712	23,535
						4.25	140	20	1,167	17,661
UT	A5	IR-80	4.87	12,860	TCB	3	40	16	743	19,651
						3	40	16	722	19,094
						3	40	16	698	25,941
OR	B4	IR-5	15.62	20,550	TCB	2	8.4	28	479	7,142
						2	16	28	587	8,452
						2	64	28	1,005	14,997
OR	C6	IR-84	18.39	5,650	TCB	--	8.4	28	479	7,111
AZ	E2	IR-40	4.19	8,800	TCB	2.75	84	28	1,302	21,840
						2	84	28	1,252	20,615
AZ	E6	IR-10	0.20	12,000	TCB	1.75	84	22	1,593	36,143
						1.75	84	22	1,831	42,870
						1.75	84	22	1,353	33,750
NC	E9	US-1 SB	0.10	15,000	AC Div.	4	36	14	618	9,442
						4	36	14	618	12,336
KY	F9	WKP	1.70	4,200	Tubes	3	30	14	640	15,155
						3	30	14	678	16,065
						3	30	14	537	12,716
LA	F6	IR-59	5.54	12,980	Tubes	5	128	24	785	70,605
LA	F7	IR-20	2.68	27,590	Tubes	5	64	24	369	53,068
LA	F9	IR-20	6.76	13,530	AC Div.	5	64	24	425	43,734
						5	64	24	382	39,346
						5	64	24	344	35,473
LA	F15	IR-20	7.21	23,870	Tubes	5	64	24	344	37,884
						4.5	70	16	1,300	28,768
MI	G3	IR-69	2.02	15,500	TCB	--	70	16	1,300	39,750
UT	G6	IR-84	14.15	3,845	Drums	1.5	64	22	1,392	43,312
						1	40	22	1,161	36,124
						3	64	32	1,228	51,073
				RANGE HIGH =		5.0	140.0	32.0	1,831	70,605
				AVERAGE =		3.2	59.1	21.4	885	27,466
				RANGE LOW =		1.0	8.4	12.0	344	7,111

Table 14. TLTWO median crossover features and costs (two way).

Project Number		Route	Project Length (miles)	ADT	Primary Chan. Device	Degree of Curve	Median Width (feet)	Pavt. & Shldr. Width (feet)	X-over Length (feet)	Crossover Cost ($)
LA	E1	US-190	1.19	16,000	Tubes	8	188	23	811/837	188,555
						8	44	23	479/492	110,835
WV	E5	IR-64	0.89	27,000	TCB	3	40	14	970	38,918
WV	E6	IR-77	0.60	9,300	TCB	4	40	14	1,047	52,491
						4	40	14	970	57,225
MI	F6	IR-96	8.20	12,800	AC Div.	5	70	16	1,300	12,989
NC	F4	IR-40	8.96	17,000	AC Div.	5	36	36 X 650	36 X 650	20,017
KY	G1	IR-75	0.40	23,000	Cones	--	60	12	750	35,520
				RANGE HIGH =		8	188	36	1,300	188,555
				AVERAGE =		5	65	17	851	64,569
				RANGE LOW =		4	36	14	479	12,989

percent respectively) because of the extensive construction work involved and the need to separate traffic from the work site by the use of positive barriers or the TLTWO strategy in most cases.

(4) The AC pavement overlay projects (resurfacing and type C) with a range of traffic control costs of 1.46 to 11.11 percent had the lowest average costs for traffic control.

Alternate Traffic Control Cost Estimates

Variations in items of work and the basis of payment (many lump sum costs), as well as voids in comparable work in the study projects within a given State, complicated the task of estimating alternate traffic control costs. In addition, as previously discussed under the "Alternate Traffic Control Analysis" section, several States indicated that the SLC was not an acceptable alternative for the concrete pavement recycling/overlay and reconstruction projects (types A and F). The SLC alternate traffic control cost analyses for these projects were performed as shown in the sample in table 10. The high SLC alternate TCP costs for type A and F projects are summarized in table 9 and provides an economical basis for supporting the "no feasible alternative traffic control strategy" to the TLTWO strategy on these projects.

Because of the lack of common costs among the study projects and participating States, it was found desirable, where possible, to use unit prices and costs from the same State to develop a basis for estimating costs for the alternate method of traffic control that was not specified during construction of the project. As a result where traffic control measures on different projects were similar, the prices per unit of work for each unit length were used for the alternate estimates for traffic control as presented in Table 9.

In summary the alternate traffic control cost analyses performed demonstrate that the methods of traffic control strategy selected for construction study projects were found to be sound, except where contractors chose to submit an alternate that would better suit their needs. This occured on two projects: Michigan project G3, where the contractor received an approved alternative to use TLTWO at no additional cost; (This may still be under debate in arriving at final costs.) and Arizona project E2, where the contractor developed a structural technique and received an approval to use a SLC at a considerable savings to the State and shared with the contractor.

Accident Analysis

Accident data were collected from 10 States for a total of 50 of the 51 construction study projects, excluding California project A1. Each State's data was provided in variety of formats. Although most States submitted only a single record for each accident, some States, such as Utah, reported on each vehicle in an accident as a record, and hence the data had to be screened to avoid duplicate counts.

Accident data were collected for 3 years prior to the construction period for each study project. For projects of less than one year's duration, the comparable months were abstracted for the 3 year before period, (i.e. if a project ran from January 1, 1985 to June 30, 1985, only data for the months of January to June were abstracted in the before years). If a project was ongoing for more than a year, all before data were used. In most cases, at least 3 years of before data were available.

The variables recorded for each accident were: date (month, day, year), time (hour), am or pm, day or night, day of week, weather conditions, road conditions, accident severity, and single or multiple vehicle. These variables were hand coded onto coding sheets and then entered into ASCII files on an IBM-XT PC. The data were then edited and rechecked against the accident coding forms to insure accuracy. Since some of the data arrived sporadically and revisions were received from some of the States after data had been entered, this required the analyst to ensure duplicate accidents did not get into the data sets. There were also problems in ensuring similar beginning and ending milepoints and dates for the before and during construction periods. This effort required much more time than had been planned or anticipated. For one State it was discovered that the data contained accidents for interchange crossroad approches (off freeway) within the construction project limits. Revised data were obtained which corrected the problem.

All data collected were coded into the computer. Because of major incompletions (i.e., not all States reported road condition) and inconsistencies (some States did not code am or pm and day/night, or the day of week was not available), many of these variables were not used in the analysis.

Table 15 shows the results of the accident data compiled for each construction study project. The before and during construction study periods are presented by number of months in columns 5 and 6. The number of accidents for each project were tabulalated and are listed for both the before and during construction periods in columns 7 and 8. Property damage only (PDO) accidents (columns 9 and 10) and injury and fatal (I & F) accidents (columns 11 and 12) are listed separately for the before construction and during construction periods respectively.

Table 15. Accident data summary by project and state.

(1) Project Number	(2) Type Control Used	(3) Acc. Section Length (Miles)	(4) Average Daily Traffic (ADT)	(5) Period Before (Mos)	(6) Period During (Mos)	(7) Total Accs. Before	(8) Total Accs. During	(9) P.D.O. Accs. Before	(10) P.D.O. Accs. During	(11) I & F Accs. Before	(12) I & F Accs. During	(13) Acc. Rate Before	(14) Acc. Rate During	(15) Acc. Rate Change
NC F1	SLC	—	15,000	—	—	—	—	—	—	—	—	—	—	—
UT A5	TLTWO	0.60	12,860	—	—	—	—	—	—	—	—	—	—	—
WV D3	SLC	2.69	19,000	3	1	2	4	1	3	1	1	1.587	9.522	7.935
MI C10	SLC	9.90	24,500	33	11	284	174	226	120	58	54	4.317	7.935	3.618
NC G13	SLC	3.44	30,000	43	21	56	79	39	51	17	28	1.535	4.435	2.900
MI G3	TLTWO	6.11	15,500	28	15	20	43	19	33	1	10	1.397	4.239	2.841
UT C3	SLC	16.25	4,543	6	2	11	7	6	4	5	3	3.022	5.768	2.747
FL C15	SLC	4.80	20,000	36	12	142	72	64	35	78	37	4.999	7.604	2.605
AZ C5	SLC	6.10	5,900	18	6	6	5	4	4	2	1	0.939	3.381	2.442
WV D8	SLC	4.16	6,200	53	17	22	18	16	11	6	7	2.657	4.971	2.313
NC E9	TLTWO	1.82	15,000	35	19	21	19	13	9	8	10	2.674	4.457	1.783
WV E6	TLTWO	2.60	9,300	36	12	18	10	12	6	6	4	2.516	4.193	1.677
LA C3	SLC	11.00	24,070	36	15	130	101	74	39	56	62	1.659	3.094	1.435
NC F5	SLC	9.93	32,000	47	13	163	93	100	51	63	42	1.328	2.739	1.411
NC F4	TLTWO	11.70	17,000	37	12	124	67	67	45	57	22	2.050	3.415	1.365
OR A1	TLTWO	7.06	24,200	36	25	36	65	16	33	20	32	0.712	1.780	1.068
KY G1	TLTWO	4.00	23,000	27	9	30	17	22	12	8	5	1.469	2.498	1.029
OR C6	SLC	18.39	5,550	18	6	31	15	15	7	16	8	2.053	2.980	0.927
NC C17	SLC	13.07	41,300	31	18	248	213	143	120	105	93	1.803	2.667	0.864
KY C4	SLC	14.40	7,590	31	15	64	42	45	25	19	17	2.298	3.117	0.819
OH B1	SLC	6.89	25,358	18	6	46	22	35	16	11	6	1.754	2.517	0.763
NC F2	TLTWO	16.89	25,000	35	30	119	177	65	109	54	68	0.980	1.700	0.720
NC C3	SLC	7.35	30,000	42	15	154	74	96	35	58	39	2.023	2.722	0.699
OR B4	SLC	15.52	20,550	36	16	28	33	18	10	10	23	0.297	0.787	0.490
LA F6	TLTWO	6.60	12,980	36	22	84	56	50	34	34	22	3.314	3.615	0.301
MI F8	TLTWO	10.00	18,500	33	11	240	101	175	75	65	26	3.886	4.185	0.299
LA F7	TLTWO	4.70	27,590	36	16	61	32	36	16	25	16	1.590	1.877	0.287
AZ G7	SLC	3.30	33,000	30	10	121	42	94	33	27	9	4.506	4.692	0.186
NC B7	SLC	7.80	35,000	14	17	76	98	53	58	23	40	2.419	2.569	0.150
OR C8	SLC	16.89	12,425	15	5	27	10	12	2	15	8	1.044	1.160	0.116
FL C16	SLC	7.52	26,000	36	18	193	99	81	42	112	57	3.336	3.423	0.086
OR A2	TLTWO	13.18	22,550	36	31	86	79	41	43	45	36	0.978	1.043	0.065
MI D5	SLC	3.00	11,400	6	2	8	2	7	1	1	1	0.000	0.000	0.000
LA C4	SLC	14.80	21,610	21	7	70	23	41	11	29	12	1.268	1.250	-0.018
NC B8	SLC	11.57	20,000	20	19	72	67	49	29	23	38	1.893	1.854	-0.039
LA F9	TLTWO	8.80	13,530	36	21	60	33	35	16	25	17	1.703	1.606	-0.097
AZ E6	TLTWO	2.20	12,000	24	8	13	4	10	4	3	0	2.496	2.304	-0.192
UT G6	TLTWO	10.70	3,845	48	48	53	49	37	36	16	13	3.265	3.019	-0.246
LA B14	SLC	6.10	23,470	6	2	8	2	1	1	7	1	1.133	0.850	-0.283
KY F9	TLTWO	5.50	4,200	36	12	14	4	8	2	6	2	2.048	1.756	-0.293
MI A2	TLTWO	10.00	29,000	18	6	119	44	89	36	30	8	2.884	2.535	-0.350
FL G5	TLTWO	2.80	4,900	36	24	21	13	13	7	8	6	5.173	4.803	-0.369
AZ E2	SLC	6.20	8,800	36	13	40	12	24	9	16	3	2.478	2.058	-0.419
KY D7	SLC	8.00	26,000	24	8	75	25	54	19	21	6	1.414	0.877	-0.536
AZ C11	SLC	14.09	8,000	24	8	153	43	80	20	73	23	6.881	5.802	-1.079
MI F6	TLTWO	12.00	12,800	24	8	173	35	136	26	37	9	5.104	3.062	-2.042
LA E1	TLTWO	2.40	16,000	36	25	108	56	62	25	46	31	9.505	7.097	-2.408
WV E5	TLTWO	2.05	27,000	36	12	90	16	59	11	31	5	5.495	2.931	-2.565
UT A4	TLTWO	8.80	5,218	36	16	74	17	46	13	28	4	5.447	2.815	-2.631
LA F15	TLTWO	7.20	23,870	36	25	336	82	259	39	77	43	6.607	2.322	-4.285

Acc. Rate = Accidents per 10,000 ADT.
P.D.O. = Property Damage Only.
I & F = Injury and Fatal.

These variables were used along with ADT to determine an accident rate for each project.

To compute the accident rates it was necessary to standardize the rates on comparable units. Since the before and during periods covered different time periods, an average accident per day rate was computed using 30 days per month. This daily rate was then divided by the section length in miles (ending minus beginning milepoints) and the ADT to produce an accident per day per mile per unit ADT rate.

It was determined that a rate based on an ADT of 10,000 would be suitable. The accidents per day per mile rate was therefore multiplied by 10,000. The rate was then scaled up by 365 days per year to reflect an annual rate per mile for 10,000 vehicles for each project. The final accident rate combined with other data for each study project, before and during construction, is shown in columns 13 and 14 of table 15.

The yearly accident rate change is then the difference between the before and the during accident rates as shown in column 15 of the table. An increase in the accident rate during construction is shown as a positive number in this column, while a reduction in the rate of accidents is shown as a negative (-) number. The projects are listed in table 15 and ranked by those with the greatest increase in accident rate change during construction at the top, to the greatest decrease at the bottom.

Worker Accidents

Construction worker or pedestrian accidents were not coded separately in any of the data collected, but contacts were made with project/resident engineers' offices for all projects to obtain confirmation of worker accidents experienced on each project. There was only 1 known traffic related accident within the 50 construction study projects involving workers. It was a one-vehicle fatality involving a worker who fell asleep while driving a truck.

Several other minor non-traffic related accidents to workers were reported by the project representatives contacted. The conclusion from the research study involving the 50 projects is that there is no statistical significance to accidents involving construction workers or when comparing the SLC or TLTWO traffic control strategies.

Statistical Analysis--Results and Conclusions

The statistical method used to analyze this data was the analysis of variance (ANOVA) on the log transformation of accident rate. The log transformation is the recommended transformation to use when analyzing rates because it tends to stabilize the variance, thus satisfying a necessary assumption required of the analysis of variance method--namely that the dependent variable (accident rate) be normally distributed. A two-way ANOVA was run using data from 48 of the projects with main effects of time (before versus during), treatment (SLC versus TLTWO) and time by treatment interaction incorporated in the ANOVA model. The hypotheses being tested by these model variables are:

(1) Main effect treatment: Is there a significant difference in the accident rates for TLTWO versus SLC over the entire time period these data were collected? (i.e., combining both before and during time periods).

(2) Main effect time: Is there a significant difference in the accident rates before construction versus during construction for all projects? (i.e., combining SLC and TLTWO projects).

(3) Interaction: Is there a significant difference in accident rates from before to during construction for SLC projects and TLTWO projects? (i.e., was there an increase in accident rates and was this increase different for SLC projects than for the TLTWO projects?).

The results of this analysis are summarized in table 16. The sample sizes (number of construction projects), mean and standard deviation (s.d.) of the log transformed accident rates, and mean accident rates (untransformed) are shown. These same rates are shown for I & F accidents only. They were computed by subtracting the PDO accidents from the total accidents. The 25 SLC projects had a mean total accident rate of 1.9570 before construction and 2.8682 during, whereas the 22 TLTWO projects had a mean total rate of 2.6211 accidents before and 2.7832 accidents during. For I & F accidents, the SLC projects had a mean of 0.7601 before and 1.2340 during construction and the TLTWO projects had a mean of 0.8390 before and 1.0523 during construction.

For total accidents, none of the model parameters were statistically significant at the 0.05 level of significance as determined using the ANOVA method of analysis. This means that the answers to the 3 questions outlined above in the hypothesis were all "no." There was no statistically significant difference in any of the total accident rates. However, for the more severe accidents there was a statistically significant increase in accidents during construction of the study projects. This means that the answer to question 2 is "yes" for the F & I accident rates, but "no" to questions 1 and 3.

Another analysis was done for the SLC projects and TLTWO projects separately. That is, one-way ANOVAs were run and the question addressed was "Is there a significant increase in the accident rates (total and more severe) from before to during

Table 16. Discriptive statistics for accident rates.

Type Traffic Control	Construction Period	Sample Size (N)	Mean	Mean (log)	S.D. (log)
TOTAL ACCIDENTS					
SLC	Before	25	1.9570	0.6714	0.6411
	During	25	2.8682	1.0537	0.6959
TLTWO	Before	22	2.6211	0.9636	0.6797
	During	22	2.7832	1.0236	0.4472
FATAL AND INJURY ACCIDENTS					
SLC	Before	25	0.7601	-0.2737	0.6700
	During	25	1.2340	0.2103	0.6327
TLTWO	Before	22	0.8390	-0.1756	0.8771
	During	22	1.0523	0.0510	0.5158

construction, if we look at only SLC projects separately from TLTWO projects?" This analysis controls for difference in the variability of accident rates for the 2 types of treatments. When the question is posed in this manner, there is a slight (but very marginal) statistically significant increase in both total accidents and more severe accidents for the SLC sites (p-values = 0.049 and 0.011, respectively--less than 0.05 is "statistically significant"), but not for the TLTWO projects (p-values = 0.73 and 0.31, respectively). Recall from the mean rates, this statistically significant increase is less than one accident per year per 10,000 vehicles (1.957 - 2.868 = -0.91) for total accidents and 0.7601 - 1.2340 = -0.4740 for more severe accidents) --a result which is of questionable "practical" significance.

Projects were grouped according to types as follows: all A (Concrete Pavement Recycling/Overlay) and F (Reconstruction) projects, all D (Bridge Deck Overlay) and E (Bridge Deck Replacement/Widening) projects, and all C (Asphalt Concrete Pavement Overlay) projects only. Table 17 shows the descriptive statistics for these analyses. Again, there was no significant difference from before to during accident rates for any of these project types, including the separate ANOVA analyses that were performed.

Another analysis was conducted to see if there was any pattern of accident rate change from before to during for all the projects using table 15. West Virginia project D3 had the greatest increase of 7.9 accidents per year per 10,000 vehicles. Note that the SLC

Table 17. Discriptive statistics for various types of construction projects.

Project Type (#)	Type Traffic Control	Construction Period	Sample Size (N)	Mean	Mean (log)	S.D. (log)
TOTAL ACCIDENTS						
C	SLC	Before	13	2.309	0.8370	0.6048
		During	13	3.364	1.2131	0.5938
D & E	SLC	Before	4	1.960	0.6731	0.3157
		During	4	3.040	1.1121	1.0394
	TLTWO	Before	5	3.877	1.3553	0.6009
		During	5	3.894	1.3595	0.4301
A & F	TLTWO	Before	13	2.309	0.8367	0.7094
		During	13	2.275	0.8221	0.3953
FATAL AND INJURY ACCIDENTS						
C	SLC	Before	13	0.782	-0.2460	0.6492
		During	13	1.557	0.4426	0.5799
D & E	SLC	Before	4	0.662	-0.2460	0.6492
		During	4	1.131	0.1238	0.8013
	TLTWO	Before	5	1.304	0.2655	0.7658
		During	5	1.939	0.6625	0.6106
A & F	TLTWO	Before	13	0.868	-0.1413	0.5037
		During	13	0.878	-0.1300	0.3511

(*) Type A--Concrete pavement recycling/overlay
Type C--Asphalt concrete pavement overlay
Type D--Bridge deck overlay
Type E--Bridge deck replacement/widening
Type F--Reconstruction

projects tend to rank higher and are "clustered" toward the top half of the list whereas the TLTWO sites tend to "cluster" at the bottom half. A non-parametric statistical test, the Wilcoxon test, was used to answer whether this "clustering" was statistically significant from what one would have expected by chance. The result of the test was that there does appear to be a statistically significant difference (p-value = 0.0395) in the ranks of these projects by treatment (type of traffic control). That is, SLC projects tend to show more of an increase and TLTWO projects more of a decrease in accidents during construction.

All analyses were run on the SAS (Statistical Analysis System) version 6.03 for the IBM PC.

Field Traffic Study Results for Measurable Delay

As mentioned previously the research originally anticipated that traffic field studies to measure delay would be conducted at suitable projects selected for construction study. Since possible delays were considered and actually field studied at only 3 construction study projects, other sites were selected for the majority of the traffic studies. The following summarizes the findings from the traffic studies conducted.

<u>Construction Projects Using TLTWO</u>

Site Characteristics

Tables 18 and 19 summarize the characteristics in the crossover direction and the opposite direction for the 12 TLTWO study sites. Eleven of the sites were on freeways and turnpikes and 1 of the sites was on an arterial that crossed a turnpike. Data were collected, for the most part, during periods when the highest demand volumes were anticipated. The lone exception was the data in Kentucky that were collected during off-peak periods by an agent of the Kentucky Department of Transportation. For the 12 study sites, data were collected on weekdays at 7 of the sites and on weekends at the other 5 sites.

Temporary concrete barriers were used to divide the opposing flows of traffic at 8 sites, plastic tubes were used at 3 sites and cones at 1 site. The minimum travelway width (lane and shoulder) in the crossover direction ranged between 11.0 and 16.0 ft., and ranged between 11.33 and 23.75 ft. in the opposing direction. The length of the TLTWO ranged between 0.1 and 11.2 miles, with the shorter lengths involving highway bridge improvement projects. Bridge decks had the minimum travelway width on several of the projects.

Table 18. Site characteristics--TLTWO crossover direction.

Study Number	Date	Field Site	Type of Highway	Highway	Minimum Travelway Width (ft)	Length of TLTWO (mi)	Type of Divider	Period Of Day	Period Of Week	Vehicle Occupancy (ppv)
1	6/08/87	FL-1	Turnpike	I95 -NB	12.0	0.7	PCB	Peak	Weekday	1.62
2	6/09/87	FL-2	Arterial	SH84-WB	11.0	0.4	PCB	Peak	Weekday	1.34
3	8/23/87	WI-1	Freeway	I90 -EB	15.0	5.0	Tubes	P.M.	Sunday	1.75
4	9/04/87	MN-1	Freeway	I35E -NB	16.0	11.2	Tubes	P.M.	Friday	1.92
*5	5/26/87	KY-1	Freeway	I75 -SB	15.0	0.7	Cones	Off-Peak	Weekday	1.57
6	5/05/88	WV-3	Freeway	I64 -EB	14.0	1.1	PCB	A.M.	Weekday	1.30
7	5/24/88	KS-1	Freeway	I35 -NB	16.0	9.0	PCB	A.M.	Weekday	1.47
8	5/26/88	KS-2	Freeway	I235 -SB	14.5	7.5	PCB	A.M.	Weekday	1.40
9	8/14/88	OK-1	Freeway	I40 -WB	14.0	2.0	PCB	P.M.	Sunday	1.65
10	8/26/88	OK-2	Freeway	I40 -EB	14.0	0.1	PCB	P.M.	Friday	1.44
11	8/21/88	WI-2	Freeway	I94 -EB	14.5	4.0	Tubes	P.M.	Sunday	1.56
12	9/01/88	WV-4	Freeway	I64 -WB	14.33	1.1	PCB	P.M.	Weekday	1.35

* Data collected by State or State agent

ft = feet
mi = miles
ppv = persons per vehicle

Table 19. Site characteristics--TLTWO opposite direction.

Study Number	Date	Field Site	Type of Highway	Highway	Minimum Travelway Width (ft)	Length of TLTWO (mi)	Type of Divider	Period Of Day	Period Of Week	Vehicle Occupancy (ppv)
1	6/08/87	FL -1	Turnpike	I95 -SB	19.75	0.7	PCB	Peak	Weekday	1.40
2	6/09/87	FL -2	Arterial	SH84-EB	11.33	0.4	PCB	Peak	Weekday	1.21
3	8/23/87	WI -1	Freeway	I90 -WB	22.0	5.0	Tubes	P.M.	Friday	1.88
4	9/07/87	MN-1	Freeway	I35E -SB	22.0	11.2	Tubes	P.M.	Monday	1.73
*5	5/26/87	KY -1	Freeway	I75 -NB	22.0	0.7	Cones	Off-Peak	Weekday	1.61
6	5/04/88	WV-3	Freeway	I64 -WB	21.0	1.1	PCB	P.M.	Weekday	1.48
7	5/24/88	KS -1	Freeway	I35 -SB	20.0	9.0	PCB	P.M.	Weekday	1.51
8	5/25/88	KS -2	Freeway	I235 -NB	14.5	7.5	PCB	P.M.	Weekday	1.22
9	8/12/88	OK-1	Freeway	I40 -EB	16.0	2.0	PCB	P.M.	Friday	1.59
10	8/28/88	OK-2	Freeway	I40 -WB	21.0	0.1	PCB	P.M.	Sunday	–
11	8/19/88	WI -2	Freeway	I94 -WB	–	4.0	Tubes	P.M.	Friday	1.66
12	9/02/88	WV-4	Freeway	I64 -EB	23.75	1.1	PCB	A.M.	Weekday	1.60

* Data collected by State or State agent

ft = feet
mi = miles
ppv = persons per vehicle

Capacities

Tables 20 and 21 summarize the maximum measured flow and the average sustained flow for the crossover direction and the opposite direction. The maximum flow was measured during 1 full hour; the average sustained flow was the volume measured for consecutive periods exceeding 1 hour. Data are tabulated in terms of vehicles per hour and equivalent passenger cars per hour. A truck equivalency factor of 2.0 was used to convert to equivalent passenger cars.[5]

Traffic capacity through a TLTWO section can be measured during periods when traffic demand is higher than the capacity of the single lane. Thus, unless construction activities or a narrow bridge within the TLTWO section affected traffic flow, congestion would originate at the location where the highway section was reduced from two to one lane. Traffic flow through the TLTWO section would, therefore, constitute the capacity under saturated flow conditions.

Previous studies[3] indicated that the sustained capacity under saturated flow is approximately 1,500 vph in the crossover direction and 1,800 vph in the opposite direction. The results of the field studies of this project reported herein seem to confirm these values.

The original intent was to collect data during saturated flow conditions described above. Every attempt was made to coordinate with the highway agency at each site to ensure that the research principals could make arrangements (i.e., hire field personnel for specific days, travel to the study site, set up traffic counters, etc.) to collect data on days when congestion was, according to the agency, certain to occur. However, as indicated in tables 20 and 21, these quality control procedures to collect data during saturated flow conditions were less than succussful. In spite of the coordination measures by the researchers, saturation flows did not exist in the crossover direction at 6 sites and in the opposite direction at 4 sites when the data were actually collected. Accidents occurred during data collection at 2 other sites in the opposite direction which adversely affected the flow through the work zone. In all these cases, the maximum measured volumes were, as expected, less than 1,500 vph in the crossover direction and less than 1,800 in the opposite direction.

Of the 5 freeway and turnpike sites (WI-2, WV-4, FL-1, WI-1, MN-1) that did experience saturated flows in the crossover direction during the field studies, only 2 sites experienced sustained flows of 1,500 vph or more. The sites, WI-2 and WV-4, resulted in sustained flows of 1,560 vph (1,600 passenger cars per hour[pcph]) and 1,530 vph (1,650 pcph).

Table 20. Summary of field studies--TLTWO crossover direction.

Study Number	Field Site	Width of Travelway (ft)	Length of TLTWO (mi)	Maximum** Measured Flow (vph)	Average** Sustained Flow (vph)	Maximum** Measured Flow (pcph)	Average** Sustained Flow (pcph)
1	FL -1	12.0	0.7	1480	1450	1580	1550
2	FL -2	11.0	0.4	1540	1450	1630	1540
3	WI -1	15.0	5.0	1320	1315	1450	1440
4	MN-1	16.0	11.2	1100	1010	1120	1030
*5	KY -1	15.0	0.7	***	***	***	***
6	KS -1	16.0	9.0	1200***	1300***	1380***	1300***
7	KS -2	14.5	7.5	1120***	1110***	1220***	1180***
8	OK-1	14.0	2.0	1490***	1470***	1590***	1560***
9	OK-2	14.0	0.1	1390***	1350***	1480***	1450***
10	WI -2	14.5	4.0	1580	1560	1620	1600

*Data collected by State or State agent (Off-peak data)
**Under saturated flow conditions
***Data were not collected under saturated flow conditions

ft = feet
mi = miles
vph = vehicles per hour
pcph = passenger cars per hour

Table 21. Summary of field studies--TLTWO opposite direction.

Study Number	Field Site	Width of Travelway (ft)	Length of TLTWO (mi)	Maximum** Measured Flow (vph)	Average** Sustained Flow (vph)	Maximum** Measured Flow (pcph)	Average** Sustained Flow (pcph)
1	FL -1	19.75	0.7	1700	1500	1860	1650
2	FL -2	11.38	0.4	1540	1500	1580	1570
3	WI -1	22.0	5.0	1330	1310	1550	1520
4	MN-1	22.0	11.2	1370xxx	---	1380xxx	---
*5	KY -1	22.0	0.7	***	***	***	***
6	KS -1	20.0	9.0	1840	1810	1950	1910
7	KS -2	14.5	7.5	1300***	1250***	1470***	1400***
8	OK-1	15.0	2.0	1450***	1410***	1540***	1500***
9	OK-2	14.0	0.1	1420***	1400***	1490***	1460***
10	WI -2	---	4.0	1660	1620	1800	1750

*Data collected by State or State agent (Off-peak data)
**Under saturated flow conditions
***Data were not collected under saturated flow conditions
xxxAccident and/or stalled vehicle and/or contractor stopped traffic

ft = feet
mi = miles
vph = vehicles per hour
pcph = passenger cars per hour

The other 3 freeway and turnpike study sites (FL-1, WI-1, MN-1) experienced sustained flows in the crossover direction during saturated flow conditions which were less than 1,500 vph. In all 3 cases, work activities (curious motorists) and/or geometrics within the TLTWO section adversely affected traffic flow. Even though traffic at the lane closure could theortically accommodate approximately 1,500 vph, conditions within the TLTWO sections resulted in reduced flows. Measurements at sites FL-1, WI-1 and MN-1 resulted in sustained flows of only 1,450 vph (1,550 pcph), 1,315 vph (1,440 pcph) and 1,010 vph (1,030 pcph). It should be noted that there were large percentages of camper vehicles during the studies at sites WI-1 and MN-1. The lengths of the TLTWO sections were 0.7, 5.0 and 11.2 miles at sites FL-1, WI-1 and MN-1.

At the 1 arterial street site, sustained flows of 1,450 vph (1,540 pcph) were measured in the crossover direction.

Table 21 reveals that, of the 4 freeway and turnpike study sites (KS-1, WI-2, FL-1, WI-1) that did experience saturated flows in the opposite direction during the field studies, the average sustained flows were approximately 1,800 vph at only one site. Site KS-1 experienced sustained flows of 1,810 vph (1,910 pcph). The flows at sites WI-2, FL-1 and WI-1 were adversely affected by the work activities within the TLTWO sections and resulted in sustained flows of only 1,620 (1,750 pcph), 1,500 vph (1,650 pcph) and 1,310 vph (1,520 pcph).

At the one arterial street site, sustained flows of 1,500 vph (1,570 pcph) were measured in the direction opposite to the crossover.

Construction Projects Using SLC

Site Characteristics

Table 22 summarizes the characteristics of the 13 SLC sites. All of the studies were conducted on freeways. Comparable to the TLTWO sites, data were to be collected during periods of the day when congestion existed as a result of the lane closure. Data were collected during weekday peak periods at all sites with the exception of 3 sites where the data were collected during the off-peak hours.

The traffic control devices used to separate the workers from the open traffic lane varied among sites and included cones, drums, barricades and temporary concrete barriers. The width of the travelway for the open traffic lane ranged from 12.0 to 24.0 ft.

Capacities

Table 23 summarizes the maximum measured flow and the average

Table 22. Site characteristics--SLC (closure direction).

Study Number	Date	Field Site	Type of Highway	Highway	Width of Travelway (ft)	Type of Divider	Period Of Day	Period Of Week	Vehicle Occupancy (ppv)	Comments
1	7/09/87	TX-1	Freeway	I35-NB	12.0	Cones	Off-Peak	Weekday	--	Crane adjacent to traveled way
2	7/09/87	TX-2	Freeway	I35-SB	12.0	Cones	Off-Peak	Weekday	--	Crane adjacent to traveled way
3	2/09/97	AR-1	Freeway	I10-WB	14.0	PCB	Peak	Weekday	1.56	
4	2/10/87	AR-2	Freeway	I10-EB	14.0	PCB	Peak	Weekday	1.43	
5	8/03/87	MI-1	Freeway	I94-WB	17.2	PCB	Peak	Weekday	1.71	Contractor stopped traffic
6	8/04/87	MI-3	Freeway	I94-WB	20.8	PCB	Peak	Weekday	1.71	No congestion
7	8/05/87	MI-4	Freeway	I94-EB	20.8	PCB	Peak	Weekday	1.57	
8	8/11/87	WV-1	Freeway	I64-WB	16.0	Barricades	Peak	Weekday	1.43	
9	8/12/87	WV-2	Freeway	I64-EB	18.0	Drums	Peak	Weekday	1.67	No congestion
* 10	8/19/87	KY-2	Freeway	I71-NB	16.0	Drums	Off-Peak	Weekday	1.54	No congestion
* 11	8/19/87	KY-3	Freeway	I71-SB	16.0	Drums	Peak	Weekday	1.22	
12	10/30/87	OH-1	Freeway	I75-SB	22.0	Drums	Peak	Weekday	1.69	
13	11/06/87	OH-2	Freeway	I75-SB	24.0	Drums	Peak	Weekday	1.78	No congestion

*Data collected by State or State agent

ft = feet
ppv = persons per vehicle

Table 23. Field study results--SLC (closure direction).

Study Number	Date	Field Site	Width of Travelway (ft)	Maximum** Measured Volume (vph)	Average** Sustained Flow (vph)	Maximum** Measured Volume (pcph)	Average** Sustained Flow (pcph)
1	7/09/87	TX-1	12.0	1060	1060	1200	1200
2	7/09/87	TX-2	12.0	950	950	1100	1100
3	2/09/87	AR-1	14.0	1690***	1670***	1800***	1790***
4	2/10/87	AR-2	14.0	1690***	1650***	1800***	1760***
5	8/03/87	MI-1	17.2	1350xxx	1320***	1550xxx	1500***
6	8/04/87	MI-3	20.8	1370***	1300***	1530***	1420***
7	8/05/87	MI-4	20.8	1450***	1360***	1670***	1550***
8	8/11/87	WV-1	16.0	1490***	1400***	1600***	1500***
9	8/12/87	WV-2	18.0	1280xxx	1240xxx	1370xxx	1340xxx
* 10	8/19/87	KY-2	16.0	1550***	1420***	1610***	1470***
* 11	8/19/87	KY-3	16.0	1130***	--	1300***	--
12	10/30/87	OH-1	22.0	1400***	1370***	1610***	1570***
13	11/06/87	OH-2	24.0	1410***	1380***	1600***	1560***

*Data collected by State or State agent
**Under saturated flow conditions
***Data were not collected during peak flow
xxxAccident and/or stalled vehicle and/or contractor stopped traffic

ft = feet
vph = vehicles per hour
pcph = passenger cars per hour

sustained flow in the direction of the lane closure. As was the case for the TLTWO sites, the maximum measured flow was for one full hour; average sustained flows were flows measured for successive periods exceeding 1 hour.

Previous studies indicated that the capacity during a long-term SLC on a two-lane freeway section when Temporary Concrete Barriers (TCBs) are used to separate the workers from the traffic is approximately 1,800 vph.[3] The capacity during short-term closures averages about 1,500 vph, but could be less depending upon the conditions within the work site and the width of the available travelway.

Table 23 shows that the maximum measured volume and the sustained volume did not reach the 1,800 vph and 1,500 vph flows for long-term and short-term operations at any of the 13 sites. There were reasons for the lower than expected flows.

At the two Texas sites (TX-1 and TX-2), the average sustained hourly volumes were 1,060 and 950 vph (1,200 and 1,100 pcph). In these two cases, a crane was in the closed median lane lifting sections of TCBs from trucks into place in the median of the freeway. The closure required that the channelizing cones be placed in the right lane resulting in a travelway width for vehicles of only 12.0 ft (10 ft. shoulder + 2 ft. remaining in the lane). The very unusual equipment and construction operation in combination with the narrow travelway resulted in the very low flows through the work site.

Accidents occurred at two of the sites during the data collection period. An accident at one site in Michigan (MI-1) resulted in a maximum flow of only 1,350 vph (1,550 pcph). While an accident at one of the sites in West Virginia resulted in maximum flows of only 1,280 vph (1,370 pcph).

In all of the other cases, unfortunately, data were collected during time periods when traffic was not at saturated conditions (i.e., congestion was not continuously present at the lane closure location). Average measured sustained hourly volumes ranged only between 1,320 and 1,670 vph (1,500 and 1,790 pcph) even though the sites were long-term construction sites where TCBs, drums and barricades were used to separate the workers from the traffic.

Although the field studies failed to substantiate the exact values for capacities during SLC on four-lane divided highways, it did indicate that the values of 1,800 vph for long-term closures and 1,500 vph for short-term closures suggested by previous research are reasonable.[3] The average measured sustained volumes at all of the long-term sites in the study reported herein which were collected during time periods when saturation flow did not exist were less than 1,800 vph. In addition, the average measured sustained hourly volumes (1,060 and 950 vph) at the two short-term sites were consistent with previous findings.[3]

Comparative Analysis of Construction Projects

The comparison of construction costs between SLC and TLTWO by type of construction was discussed in the "Construction CostAnalysis" section, with conclusions offered for each type by construction cost without accidents or road user costs. The analysis in this section of the report will incorporate the accidents, as well as the impacts of road user costs as they affect selection of the 2 traffic control strategies.

The "Accident Analysis" section contains a discussion of the statistical aspects of the rates of accidents for each study project. Additional observations appear noteworthy regarding analysis of accidents as they relate to other specific elements of the study projects.

Accident Analysis by Type of Construction

Table 24 shows the construction study project accident rates by type of construction and the rankings of the projects based on accident rates within each type when comparing the during construction to before construction phase. (A positive rate of change indicates an increase during construction, while a minus rate of change indicates a decrease.) Weighted averages of the project accident rates for each type of construction are also presented. The following observations are offered concerning the accident rates in table 24.

(1) As mentioned previously, the West Virginia D3 project is ranked highest in rate of change with an abnormally high increase in the accident rate (7.935 accidents per mile per 10,000 ADT), during versus before. One can also note from table 15 that construction work on West Virginia D3 was completed within 3 weeks and that there were 4 accidents during construction. This was a bridge deck overlay project using SLC with drums. There were obviously some problems during construction of the project. The accident rate change demonstrates how a few accidents during a short duration project results in a high rate change that is really not representative, particularly with a small number of projects. It drastically skewed the overall accident rate for the 4 study projects in the bridge deck overlay classification. (Without WVD3, the average rate of change would be approximately 0.6 accidents/mile/10K ADT, instead of 2.428.)

(2) The construction study project experiencing the most improved accident rate (during versus before) was Louisiana F15, which had a reduced rate of -4.285 accidents per mile per 10,000 ADT. This was a reconstruction project using TLTWO with tubes separating traffic flow. A review of the project details in appendix A shows that this project experienced a considerable

Table 24. Construction study projects / annual accident rates by type of construction.

Project Number		Route	Study Length (miles)	ADT	Type TCP Used	Primary Chan. Device	Before Accs./Mi./10K ADT	During Accs./Mi./10K ADT	Change During vs. Before
(A) Concrete Pavement Recycling / Overlay (6 Projects)									
OR	A1	IR-5	7.06	24,200	TLTWO	TCB	0.712	1.780	1.068
OR	A2	IR-5 NB	13.18	22,550	TLTWO	TCB	0.978	1.043	0.065
MI	A2	IR-94	10.00	29,000	TLTWO	AC Div.	2.884	2.535	-0.350
UT	A4	IR-15	8.80	5,218	TLTWO	TCB	5.447	2.815	-2.631
UT	A5	IR-80	—	—	TLTWO	TCB	—	—	—
CA	A1	IR-80	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TOTAL =			39.04	80,968	AVERAGES =		1.869	1.912	0.043
(B) Concrete Pavement Restoration (5 Projects)									
OH	B1	IR-75	6.99	25,358	SLC	Drums	1.754	2.517	0.763
OR	B4	IR-5	15.52	20,550	SLC	TCB	0.297	0.787	0.490
NC	B7	IR-40	7.80	35,000	SLC	Drums	2.419	2.569	0.150
NC	B8	IR-95	11.57	20,000	SLC	Drums	1.893	1.854	-0.039
LA	B14	IR-20	6.10	23,470	SLC	Cone/Dr ?	1.133	0.850	-0.283
TOTAL =			47.98	124,378	AVERAGES =		1.606	1.825	0.219
(C) Asphalt Concrete Pavement Overlay (13 Projects)									
MI	C10	IR-96	9.90	24,500	SLC	Drums	4.317	7.935	3.618
UT	C3	IR-15	16.25	4,543	SLC	Drums	3.022	5.768	2.747
FL	C15	IR-295	4.80	20,000	SLC	Cone/Dr ?	4.999	7.604	2.605
AZ	C5	IR-8	6.10	5,900	SLC	TCB	0.939	3.381	2.442
LA	C3	IR-10	11.00	24,070	SLC	Drums	1.659	3.094	1.435
OR	C6	IR-84	18.39	5,550	SLC	TCB	2.053	2.980	0.927
NC	C17	IR-85	13.07	41,300	SLC	Drums	1.803	2.667	0.864
KY	C4	SR-114	14.40	7,590	SLC	Cone/Dr ?	2.298	3.117	0.819
NC	C3	IR-85	7.35	30,000	SLC	Drums	2.023	2.722	0.699
OR	C8	IR-84	16.89	12,425	SLC	Cones	1.044	1.160	0.116
FL	C16	IR-295	7.52	26,000	SLC	Cone/Dr ?	3.336	3.423	0.086
LA	C4	IR-12	14.80	21,610	SLC	Drums	1.268	1.250	-0.018
AZ	C11	IR-10	14.09	8,000	SLC	Cone/Dr ?	6.881	5.802	-1.079
TOTAL =			154.56	231,488	AVERAGES =		2.640	3.784	1.144
(D) Bridge Deck Overlay (4 Projects)									
WV	D3	IR-64	2.69	19,000	SLC	Drums	1.587	9.522	7.935
WV	D8	IR-79	4.16	6,200	SLC	TCB	2.657	4.971	2.313
MI	D5	IR-196	3.00	11,400	SLC	TCB	0.000	0.000	0.000
KY	D7	IR-75	8.00	26,000	SLC	Cone/Dr ?	1.414	0.877	-0.536
TOTAL =			17.85	62,600	AVERAGES =		1.332	3.747	2.415

Project Number		Route	Study Length (miles)	ADT	Type TCP Used	Primary Chan. Device	Before Accs./Mi./10K ADT	During Accs./Mi./10K ADT	Change During vs. Before
(E) Bridge Deck Replacement / Widening (6 Projects)									
NC	E9	US-1SB	1.82	15,000	TLTWO	AC Div.	2.674	4.457	1.783
WV	E6	IR-77	2.60	9,300	TLTWO	TCB	2.516	4.193	1.677
AZ	E6	IR-10	2.20	12,000	TLTWO	TCB	2.496	2.304	-0.192
AZ	E2	IR-40	6.20	8,800	SLC	TCB	2.478	2.058	-0.419
LA	E1	US-190	2.40	16,000	TLTWO	Tubes	9.505	7.097	-2.408
WV	E5	IR-64	2.05	27,000	TLTWO	TCB	5.495	2.931	-2.565
TOTAL =			17.27	88,100	AVERAGES =		4.719	3.908	-0.811
(F) Reconstruction (11 Projects)									
NC	F5	IR-77	9.93	32,000	SLC	Mov. TCB	1.328	2.739	1.411
NC	F4	IR-40	11.70	17,000	TLTWO	AC Div.	2.050	3.415	1.365
NC	F2	IR-40	16.89	25,000	TLTWO	TCB	0.980	1.700	0.720
LA	F6	IR-59	6.60	12,980	TLTWO	Tubes	3.314	3.615	0.301
MI	F8	IR-94	10.00	18,500	TLTWO	AC Div.	3.886	4.185	0.299
LA	F7	IR-20	4.70	27,590	TLTWO	Tubes	1.590	1.877	0.287
LA	F9	IR-20	8.80	13,530	TLTWO	AC Div.	1.703	1.606	-0.097
KY	F9	WKP	5.50	4,200	TLTWO	Tubes	2.048	1.756	-0.293
MI	F6	IR-96	12.00	12,800	TLTWO	AC Div.	5.104	3.062	-2.042
LA	F15	IR-20	7.20	23,870	TLTWO	Tubes	6.607	2.322	-4.285
NC	F1	IR-40	—	—	SLC	Drums	—	—	—
TOTAL =			93.32	187,470	AVERAGES =		2.749	2.603	-0.145
(G) New / Interchange Construction (6 Projects)									
NC	G13	IR-40	3.44	30,000	SLC	TCB	1.535	4.435	2.900
MI	G3	IR-69	6.11	15,500	TLTWO	TCB	1.397	4.239	2.841
KY	G1	IR-75	4.00	23,000	TLTWO	Cones	1.469	2.498	1.029
AZ	G7	IR-10	3.30	33,000	SLC	TCB	4.506	4.692	0.186
UT	G6	IR-84	10.70	3,845	TLTWO	Drums	3.265	3.019	-0.246
FL	G5	SR-95	2.80	4,900	TLTWO	Cone/Dr ?	5.173	4.803	-0.369
TOTAL =			30.35	110,245	AVERAGES =		2.613	4.047	1.434

problem involving the extensive replacement of tubes for separation of traffic flow during construction. The tube replacement problem on this and other TLTWO projects specifying tubes prompted Louisiana to change to the asphalt divider.

(3) The following are the results of the analysis of changes in accident rates by type of construction shown in table 24 during construction as compared with before:

(a) Type A--Concrete Pavement Recycling/Overlay and Type F--Reconstruction Projects

Analysis of these two types of construction were combined because of the similar construction methodology in both categories. Type A construction projects experienced a slight increase (+0.043), while Type F projects experienced a slight reduction (-0.145) in the average overall rate of accidents during construction. As can be seen from table 24, 14 of the 17 projects in these 2 categories utilized the TLTWO traffic control strategy. The 3 using SLC were: Project California A1 which did not have accident data collected, Project North Carolina F5 which used the movable TCB technique and an early project, North Carolina F1, constructed from 1984-86, for which accident data was not available. Referring to appendix A and the construction study project descriptions, it can be noted that there were considerable problems with traffic control in the SLC on North Carolina F1 during construction. Extensive modifications were made to traffic control on this project which may have contributed to the State's later change in policy to use TLTWO for type F (reconstruction) projects.

Seven of the study projects using TLTWO experienced a slight increase in the accident rate during construction, with the highest increase being North Carolina F4, at +1.365 accidents per mile per 10,000 ADT.

As reported previously, the effect of the use of SLC on accident rates for these projects, if any, would likely be an increase in the accident rate during construction. This would be because of the added exposure of through traffic to the construction operations in an open lane adjacent to the work site, when continuous pavement is being removed and new full depth paving or concrete overlay of existing pavement work is being performed. It also would be impractical and not cost-effective to provide TCB for the SLC strategy continuously throughout projects of this type to separate motorists from the work site.

When considering these two types of construction, the research finding from the 15 projects studied for safety is that the TLTWO method is an acceptable method of traffic control from a safety standpoint for both types of construction.

(b) Type B--Concrete Pavement Restoration Projects

All 5 of the study projects utilized the SLC method of traffic control for this type of construction project and experienced a slight increase in the overall accident rate (table 24) during construction (+0.219). The highest increase in accident rate was +0.763 experienced on the Ohio B1 project.

From a safety standpoint the research finding for the 5 projects studied is that the SLC traffic control strategy is an acceptable method of handling traffic on this type of project.

(c) Type C--Asphalt Concrete Pavement Overlay Projects

This type of project had the largest sample and included 13 study projects, all of which utilized the SLC strategy for traffic control. The change in accident rates was an average increase of +1.144 accident per mile per 10,000 ADT per project during construction. Five projects had an accident rate increase above +1.0 which included Michigan C10, Utah C3, Florida C15, Louisiana C3 and Arizona C5 projects. A review of the details of these 5 projects in appendix A indicates no unusual problems reported during construction, except on Arizona C5 which had an accident involving one construction worker. As can be seen in appendix A, these projects all had extensive AC overlays (4 inches or more) and 3 projects had a substantial amount of milling, (ie., they were not simple maintenance type AC resurfacing).

From a safety standpoint and the significant increase in accident rates on the 5 referenced projects, it would appear that more complex AC overlay projects may require more extensive planning for traffic control measures. The research finding from the projects studied is that the SLC traffic control strategy may be an acceptable method of handling traffic on this type of project, but improved traffic control measures should be considered for the more complex AC overlay projects.

(d) Type D--Bridge Deck Overlay Projects

All 4 bridge deck overlay projects utilized SLC for traffic control and had a project average increase of +2.415 accidents per mile per 10,000 ADT. This type of construction project had the highest average increase rate in accidents of all the construction types studied. A significant impact on this average was the West Virginia D3 project, with an increase of +7.935, the highest individual project increase rate for all projects studied, as previously noted. As mentioned earlier, this one project skewed the average overall accident rate change for this type of project. However, the small sample size (4 projects) makes it difficult to arrive at a concensus for the safest traffic control strategy for this type of construction.

Based on the accident experience with the two West Virginia projects it would appear that there may be a need to consider a more positive separation between traffic and the work site or use of the TLTWO strategy for some bridge deck overlay projects.

(e) Type E--Bridge Deck Replacement/Widening Projects

The 6 bridge deck replacement/widening projects had an overall project average decrease of -0.811 in the accident rate during construction. Five of the projects used the TLTWO strategy, while the sixth project, Arizona E2, used the SLC, with a slight reduction in the accident rate (-0.419). It should be noted from appendix A that the Arizona E2 SLC project originally specified TLTWO, but was modified at the contractor's request and utilized a special bridge design change developed by the contractor that resulted in a significant cost savings to the project.

Based on the small sample of projects studied from a safety standpoint, there is no conclusive statistical evidence to indicate a preference on type of traffic control on this type of construction project.

(e) Type G--New/Interchange Construction Projects

These projects are not a comparative group of similar projects from a construction viewpoint or a safety standpoint. Based on the projects researched, it would appear that each project with this type of construction should be studied thoroughly during the design phase to determine whether TLTWO or SLC should be employed.

Road User Cost Impact on Type of Construction

As previously discussed, it was not possible to perform field study traffic delay impacts on road user costs for construction study projects comparing SLC and TLTWO since there was no typical measurable recurrent delay in the work zones for the construction study projects. The following analysis of road user costs was performed to develop basic parameters that may be considered for variations in costs for the 2 traffic control strategies. The finding is that road user cost comparisons between SLC and TLTWO strategies for normal traffic flow through work zones is relatively insignificant for lower traffic volumes which do not result in delays through the work zone.

A study[3], based on unimpeded flow through the work zone, using 1982 costs estimated delay costs for TLTWO road user costs at $ 0.11 per mile per vehicle for travel in a TLTWO in the crossover direction and $ 0.08 in the opposite direction of the TLTWO.

This additional cost may be considered due to the additional length traveled in the crossover direction, and some possible speed reduction through the crossovers. Thus the average cost for both directions in the TLTWO may be estimated at $ 0.095 per mile, based on the cited study. (3) The 5 TLTWO sites studied for road user costs in table 1 of this report ranged in length from 3,100 to 25,500 ft., with an average closure length of 2.52 miles. If average lane closure lengths are greater than 2.52 miles, (which is true of most of the study projects in this report, except for bridge deck replacement/widening projects, this average cost per mile would likely be reduced, since there are only 2 crossovers, one at each end of the TLTWO section, in the lane closures.

Although the referenced study did not list median width in the work zone characteristics, it must also be assumed that the median width is a primary contributor to the additional distance traveled in a TLTWO section. (The wider the median, the more distance traveled in a crossover.) In most four-lane divided highways a minimum width of approximately 40 ft. would appear to be about the minimum width that could generate any cost differentials, provided adequate crossover geometric design is available without a substantial required speed reduction. It may therefore be assumed that the $ 0.095 per mile per vehicle would be a cost that could vary for different lane closure lengths in TLTWO work zones, higher for short bridge projects and lower for projects with lane closures greater than 2.52 miles.

The same study indicated that there was no difference in road user costs for the opposite direction of traffic in a TLTWO versus SLC for equivalent work zone length, provided demand did not exceed capacity (no significant queues or impeded flow).[3] Thus for SLC projects, the average road user cost may be considered to be $ 0.08 per mile per vehicle for projects without any significant queues or impeded traffic flow.

Therefore, the cost comparison for road user costs between TLTWO and SLC strategies (in both directions) may be considered as $ 0.015 per mile per vehicle ($ 0.095 to $ 0.08). (Additional road user costs would equate to $150 per mile per 10,000 ADT.)

Traffic Control Strategy by Type of Construction

This section of the report incorporates the results in the construction cost analysis section, and the accident analysis and road user cost analysis contained in this section into research findings for use of SLC or TLTWO traffic control strategies by type of construction based on the projects studied.

As stated earlier in this report, it was not possible to measure traffic delays rough the construction study project work zones. This was because projects had either been completed or there was not sufficient traffic demand that caused a measurable delay which could be field studied to determine road user costs.

(a) Type A--Concrete Pavement Recycling/Overlay Projects

These construction improvements involve extensive work to remove existing concrete pavement/shoulders for recycling and replacement, or providing a new concrete overlay on existing pavement/shoulders. Research findings from this study indicate that construction is much more cost-effective without traffic immediately adjacent to the work site and by use of TLTWO. This was previously discussed and demonstrated by analysis of alternate traffic control costs from table 9.

Accident analysis for TLTWO on these projects indicates a very slight increase in the overall average accident rate during construction (+0.043) when compared with the before rates. Road user cost differential is insignificant between TLTWO and SLC with no measurable delay presented by construction. **RESEARCH FINDING: TLTWO**

(b) Type B--Concrete Pavement Restoration Projects

This type of construction involves intermittant removal and replacement of existing concrete pavement and shoulder sections. Work is normally performed while traffic is maintained in a SLC immediately adjacent to the work being performed. Alternate traffic control costs using TLTWO are considerably more expensive than for SLC as can be noted in table 9.

Accident analysis indicates a slight increase in the rate of accidents during construction (+.219) using SLC. Construction and contractor personnel have expressed concern for safety with through traffic adjacent as well as traffic disruptions caused by the work being performed. Accident rates do not indicate any significant safety problem with SLC. Road user cost analysis appears warranted for projects of this type to verify delays and road user costs that could offset alternate TLTWO construction costs. **RESEARCH FINDING: SLC**, with possible need for road user cost analysis for delays that could offset additional construction costs associated with TLTWO.

(c) Type C--Asphalt Concrete Pavement Overlay Projects

This type of improvement consists of the resurfacing of existing pavement with AC pavement using several passes by the paver until specified pavement overlay thickness is achieved. SLC is typically used for traffic control, and alternate cost analysis shows a substantially greater cost for TLTWO.

Accident analysis indicates an overall average accident rate increase of +1.144 during construction. The increase in accident rate during construction may be associated with the degree of complexity of work in preparation for (milling) or the need for thicker AC overlays and associated traffic control measures for the required construction work. Road user cost differential for delay with TLTWO alternative is insignificant. **RESEARCH FINDING: SLC**, with careful study of traffic control needs for complexities of placing AC overlay.

(d) Type D--Bridge Deck Overlay Projects

These projects normally involve minor repairs to the deck of an existing bridge and the placement of a latex modified overlay on the deck surface which has more salt resistance and better wearing life characteristics. SLC was used on all 4 study projects, and cost analysis of the alternate TLTWO strategy resulted in very substantial additional costs.

Accident analysis showed an overall average increase in rate of project accident rate of +2.415. Significantly high accident rates occured on 2 of the 4 construction study projects, but with a small sample it was not conclusive that TLTWO is warranted. Road user costs would slightly favor SLC because of the short average length of TLTWO travel (0.29 mile) for projects studied. **RESEARCH FINDING: SLC**

(e) Type E--Bridge Deck Replacement/Widening Projects

Projects of this type normally involve the widening bridge decks to provide greater roadway or shoulder widths and safety shapes for bridge parapet walls, or complete replacement of a structurally deteriorating bridge. Because of the narrow lateral work space on bridges, TLTWO was typically used to handle traffic on the projects studied and was specified initially for all projects studied. (One project was modified during construction to use SLC.) An alternate TCP cost analysis for the SLC was performed for 2 of the 6 study projects resulting in a significantly higher cost for SLC. No TCP alternate analysis was performed for SLC on 4 of the projects because the existing bridge structures were too narrow or the removal of the existing structure prevented use of SLC.

Accident analysis indicates that the project average rate of accidents was reduced during construction (-0.811), but with increases in the rate on two of the 6 study projects. Road user costs for TLTWO might be slightly higher, as the average length of study projects was 1.41 miles. **RESEARCH FINDING: TLTWO**

(f) Type F--Reconstruction Projects

These projects involved extensive work to rehabilitate existing highways which typically included removal and replacement of existing pavement and frequently shoulders. To provide ample work space and efficiency in performing work, TLTWO was used on 9 of the 11 construction study projects. Of the two exceptions using the SLC strategy, 1, North Carolina project F1, had significant problems with traffic control, and the other, North Carolina F5, utilized the innovative movable TCB on a project that primarily involved joint repair, some intermittant pavement replacement and an AC pavement overlay. Alternate TCP cost analyses were performed on 7 of the 11 projects, and all but 1 was significantly higher in traffic control and total construction cost. SLC on the remaining 4 projects was not considered feasible.

Accident analysis showed a reduction in the overall average rate of accidents during construction at -0.145. There is no significant difference in the road user cost for the 2 traffic control strategies. **RESEARCH FINDING: TLTWO**

(g) Type G--New/Interchange Construction Projects

These types of construction study projects involved a variety of new highway construction and were not similar in type of work. Therefore, traffic control measures could not be compared. They consisted of new highway construction, new or partial interchange construction or addition of new lanes to make a highway four-lane divided.

None of these projects are comparable as mentioned previously. Therefore there was no research finding regarding traffic control strategy. **RESEARCH FINDING: None** It is recommended that these projects be thoroughly studied to determine whether SLC or TLTWO should be used for traffic control.

Table 25 summarizes in tabular form the 7 types of construction and research findings based on the 51 projects studied concerning use of either SLC or TLTWO traffic control strategies. These projects ranged in ADT from approximately 10,000 to 30,000 and little traffic delay was encountered through the work zone.

<u>Accident Analysis by Traffic Control Strategy</u> (SLC or TLTWO)

Table 26 segregates all study projects by the two alternate traffic control strategies and lists the accident rates for each project and the project average rates for SLC and TLTWO. As concluded in the accident analysis section of this report, the TLTWO strategy has a slightly reduced rate of accidents during construction than the before rate. SLC has a larger rate of accidents during construction than the before rate.

Table 25. **Research findings for traffic control strategy by type of construction.**

Type of Construction	Strategy for Traffic Control: Construction Costs		Accident Analysis		Road User Costs		Consensus	
	SLC	TLTWO	SLC	TLTWO	SLC	TLTWO	SLC	TLTWO
Concrete Pavement Recycling/Overlay		X		X	---			X
Concrete Pavement Restoration	X		X		X?		X	Proj. Analysis
Asphalt Concrete Pavement Overlay	X		X?		X		X	
Bridge Deck Overlay	X		X		X		X	
Bridge Deck Replacement/Widening		X		X	---			X
Reconstruction		X		X	---			X
New/Interchange Construction	---		---		---			Project Analysis

Accident Analysis by Traffic Control Strategy and Channelizing Device

Table 27 presents the listing of projects within SLC and TLTWO strategies by type of channelizing device ranked in order of highest improvement of accident rate during construction.

Accident Analysis by Type of Channelizing Device

Table 28 separates study projects into categories by type of channelizing device used during construction of each project ranked by most improved rate of accidents during construction.

Table 26. Construction study projects / annual accident rates by type of control used.

Project Number		Route	Study Length (miles)	ADT	Type TCP Used	Primary Chan. Device	Before Accs./Mi./10K ADT	During Accs./Mi./10K ADT	Change During vs. Before
PRIMARY TCP = SLC									
AZ	C11	IR-10	14.09	8,000	SLC	Cone/Dr ?	6.881	5.802	-1.079
KY	D7	IR-75	8.00	26,000	SLC	Cone/Dr ?	1.414	0.877	-0.536
AZ	E2	IR-40	6.20	8,800	SLC	TCB	2.478	2.058	-0.419
LA	B14	IR-20	6.10	23,470	SLC	Cone/Dr ?	1.133	0.850	-0.283
NC	B8	IR-95	11.57	20,000	SLC	Drums	1.893	1.854	-0.039
LA	C4	IR-12	14.80	21,610	SLC	Drums	1.268	1.250	-0.018
MI	D5	IR-196	3.00	11,400	SLC	TCB	0.000	0.000	0.000
FL	C16	IR-295	7.52	26,000	SLC	Cone/Dr ?	3.336	3.423	0.086
OR	C8	IR-84	16.89	12,425	SLC	Cones	1.044	1.160	0.116
NC	B7	IR-40	7.80	35,000	SLC	Drums	2.419	2.565	0.150
AZ	G7	IR-10	3.30	33,000	SLC	TCB	4.506	4.692	0.186
OR	B4	IR-5	15.52	20,550	SLC	TCB	0.297	0.787	0.490
NC	C3	IR-85	7.35	30,000	SLC	Drums	2.023	2.722	0.699
OH	B1	IR-75	6.99	25,358	SLC	Drums	1.754	2.517	0.763
KY	C4	SR-114	14.40	7,590	SLC	Cone/Dr ?	2.298	3.117	0.819
NC	C17	IR-85	13.07	41,300	SLC	Drums	1.803	2.667	0.864
OR	C6	IR-84	18.39	5,550	SLC	TCB	2.053	2.980	0.927
NC	F5	IR-77	9.93	32,000	SLC	Mov. TCB	1.328	2.739	1.411
LA	C3	IR-10	11.00	24,070	SLC	Drums	1.659	3.094	1.435
WV	D8	IR-79	4.16	6,200	SLC	TCB	2.657	4.971	2.313
AZ	C5	IR-8	6.10	5,900	SLC	TCB	0.939	3.381	2.442
FL	C15	IR-295	4.80	20,000	SLC	Cone/Dr ?	4.999	7.604	2.605
UT	C3	IR-15	16.25	4,543	SLC	Drums	3.022	5.768	2.747
NC	G13	IR-40	3.44	30,000	SLC	TCB	1.535	4.435	2.900
MI	C10	IR-96	9.90	24,500	SLC	Drums	4.317	7.935	3.618
WV	D3	IR-64	2.69	19,000	SLC	Drums	1.587	9.522	7.935
NC	F1	IR-40	—	—	SLC	Drums	—	—	—
CA	A1	IR-80	N/A	N/A	SLC	N/A	N/A	N/A	N/A
TOTAL =			243.26	522,266	AVERAGE =		2.208	3.315	1.106

Project Number		Route	Study Length (miles)	ADT	Type TCP Used	Primary Chan. Device	Before Accs./Mi./10K ADT	During Accs./Mi./10K ADT	Change During vs. Before
PRIMARY TCP = TLTWO									
LA	F15	IR-20	7.20	23,870	TLTWO	Tubes	6.607	2.322	-4.285
UT	A4	IR-15	8.80	5,218	TLTWO	TCB	5.447	2.815	-2.631
WV	E5	IR-64	2.05	27,000	TLTWO	TCB	5.495	2.931	-2.565
LA	E1	US-190	2.40	16,000	TLTWO	Tubes	9.505	7.097	-2.408
MI	F6	IR-96	12.00	12,800	TLTWO	AC Div.	5.104	3.062	-2.042
FL	G5	SR-95	2.80	4,900	TLTWO	Cone/Dr ?	5.173	4.803	-0.369
MI	A2	IR-94	10.00	29,000	TLTWO	AC Div.	2.884	2.535	-0.350
KY	F9	WKP	5.50	4,200	TLTWO	Tubes	2.048	1.756	-0.293
UT	G6	IR-84	10.70	3,845	TLTWO	Drums	3.265	3.019	-0.246
AZ	E6	IR-10	2.20	12,000	TLTWO	TCB	2.496	2.304	-0.192
LA	F9	IR-20	8.80	13,530	TLTWO	AC Div.	1.703	1.606	-0.097
OR	A2	IR-5 NB	13.18	22,550	TLTWO	TCB	0.978	1.043	0.065
LA	F7	IR-20	4.70	27,590	TLTWO	Tubes	1.590	1.877	0.287
MI	F8	IR-94	10.00	18,500	TLTWO	AC Div.	3.886	4.185	0.299
LA	F6	IR-59	6.60	12,980	TLTWO	Tubes	3.314	3.615	0.301
NC	F2	IR-40	16.89	25,000	TLTWO	TCB	0.980	1.700	0.720
KY	G1	IR-75	4.00	23,000	TLTWO	Cones	1.469	2.498	1.029
OR	A1	IR-5	7.06	24,200	TLTWO	TCB	0.712	1.780	1.068
NC	F4	IR-40	11.70	17,000	TLTWO	AC Div.	2.050	3.415	1.365
WV	E6	IR-77	2.60	9,300	TLTWO	TCB	2.516	4.193	1.677
NC	E9	US-1 SB	1.82	15,000	TLTWO	AC Div.	2.674	4.457	1.783
MI	G3	IR-69	6.11	15,500	TLTWO	TCB	1.397	4.239	2.841
UT	A5	IR-80	—	—	TLTWO	TCB	—	—	—
TOTAL =			157.11	362,983	AVERAGE =		3.062	2.864	-0.198

Table 27. Construction study projects / annual accident rates by type of control and channelizing device used.

Project Number		Route	Study Length (miles)	ADT	Type TCP Used	Primary Chan. Device	Before Accs./Mi./10K ADT	During Accs./Mi./10K ADT	Change During vs. Before
PRIMARY TCP = SLC with CONES or DRUMS									
WV	D3	IR-64	2.69	19,000	SLC	Drums	1.587	9.522	7.935
MI	C10	IR-96	9.90	24,500	SLC	Drums	4.317	7.935	3.618
UT	C3	IR-15	16.25	4,543	SLC	Drums	3.022	5.768	2.747
FL	C15	IR-295	4.80	20,000	SLC	Cone/Dr ?	4.999	7.604	2.605
LA	C3	IR-10	11.00	24,070	SLC	Drums	1.659	3.094	1.435
NC	C17	IR-85	13.07	41,300	SLC	Drums	1.803	2.667	0.864
KY	C4	SR-114	14.40	7,590	SLC	Cone/Dr ?	2.298	3.117	0.819
OH	B1	IR-75	6.99	25,358	SLC	Drums	1.754	2.517	0.763
NC	C3	IR-85	7.[illegible]5	30,000	SLC	Drums	2.023	2.722	0.699
NC	B7	IR-40	7.80	35,000	SLC	Drums	2.419	2.569	0.150
OR	C8	IR-84	16.89	12,425	SLC	Cones	1.044	1.160	0.116
FL	C16	IR-295	7.52	26,000	SLC	Cone/Dr ?	3.336	3.423	0.086
LA	C4	IR-12	14.80	21,610	SLC	Drums	1.268	1.250	-0.018
NC	B8	IR-95	11.57	20,000	SLC	Drums	1.893	1.854	-0.039
LA	B14	IR-20	6.10	23,470	SLC	Cone/Dr ?	1.133	0.850	-0.283
KY	D7	IR-75	8.00	26,000	SLC	Cone/Dr ?	1.414	0.877	-0.536
AZ	C11	IR-10	14.09	8,000	SLC	Cone/Dr ?	6.881	5.802	-1.079
NC	F1	IR-40	—	—	SLC	Drums	—	—	—
TOTAL =			173.22	368,866	AVERAGE =		0.998	0.940	-0.058
PRIMARY TCP = SLC with TEMPORARY CONCRETE BARRIERS									
NC	F5	IR-77	9.93	32,000	SLC	Mov. TCB	1.328	2.739	1.411
NC	G13	IR-40	3.44	30,000	SLC	TCB	1.535	4.435	2.900
AZ	C5	IR-8	6.10	5,900	SLC	TCB	0.939	3.381	2.442
WV	D8	IR-79	4.16	6,200	SLC	TCB	2.657	4.971	2.313
OR	C6	IR-84	18.39	5,550	SLC	TCB	2.053	2.980	0.927
OR	B4	IR-5	15.52	20,550	SLC	TCB	0.297	0.787	0.490
AZ	G7	IR-10	3.30	33,000	SLC	TCB	4.506	4.692	0.186
MI	D5	IR-196	3.00	11,400	SLC	TCB	0.000	0.000	0.000
AZ	E2	IR-40	6.20	8,800	SLC	TCB	2.478	2.058	-0.419
TOTAL =			70.04	153,400	AVERAGE =		1.946	3.110	1.164
PRIMARY TCP = SLC with TUBES									
CA	A1	IR-80	N/A	N/A	SLC	TUBES	N/A	N/A	N/A
TOTAL =			N/A	N/A	AVERAGE =		N/A	N/A	N/A

Project Number		Route	Study Length (miles)	ADT	Type TCP Used	Primary Chan. Device	Before Accs./Mi./10K ADT	During Accs./Mi./10K ADT	Change During vs. Before
PRIMARY TCP = TLTWO with ASPHALT CONCRETE DIVIDERS									
NC	E9	US-1 SB	1.82	15,000	TLTWO	AC Div.	2.674	4.457	1.783
NC	F4	IR-40	11.70	17,000	TLTWO	AC Div.	2.050	3.415	1.365
MI	F8	IR-94	10.00	18,500	TLTWO	AC Div.	3.886	4.185	0.299
LA	F9	IR-20	8.80	13,530	TLTWO	AC Div.	1.703	1.606	-0.097
MI	A2	IR-94	10.00	29,000	TLTWO	AC Div.	2.884	2.535	-0.350
MI	F6	IR-96	12.00	12,800	TLTWO	AC Div.	5.104	3.062	-2.042
TOTAL =			54.32	105,830	AVERAGE =		3.013	3.182	0.169
PRIMARY TCP = TLTWO with CONES or DRUMS									
KY	G1	IR-75	4.00	23,000	TLTWO	Cones	1.469	2.498	1.029
UT	G6	IR-84	10.70	3,845	TLTWO	Drums	3.265	3.019	-0.246
FL	G5	SR-95	2.[illegible]	4,900	TLTWO	Cone/Dr ?	5.173	4.803	-0.369
TOTAL =			17.50	31,745	AVERAGE =		2.259	2.917	0.658
PRIMARY TCP = TLTWO with TEMPORARY CONCRETE BARRIERS									
MI	G3	IR-69	6.11	15,500	TLTWO	TCB	1.397	4.239	2.841
WV	E6	IR-77	2.60	9,300	TLTWO	TCB	2.516	4.193	1.677
OR	A1	IR-5	7.06	24,200	TLTWO	TCB	0.712	1.780	1.068
NC	F2	IR-40	16.89	25,000	TLTWO	TCB	0.980	1.700	0.720
OR	A2	IR-5 NB	13.18	22,550	TLTWO	TCB	0.978	1.043	0.065
AZ	E6	IR-10	2.20	12,000	TLTWO	TCB	2.496	2.304	-0.192
WV	E5	IR-64	2.05	27,000	TLTWO	TCB	5.495	2.931	-2.565
UT	A4	IR-15	8.80	[illegible],218	TLTWO	TCB	5.447	2.815	-2.631
UT	A5	IR-80	—	—	TLTWO	TCB	—	—	—
TOTAL =			58.89	140,768	AVERAGE =		2.242	2.382	0.140
PRIMARY TCP = TLTWO with TUBES									
LA	F6	IR-59	6.60	12,980	TLTWO	Tubes	3.314	3.615	0.301
LA	F7	IR-20	4.70	27,590	TLTWO	Tubes	1.590	1.877	0.287
KY	F9	WKP	5.50	4,200	TLTWO	Tubes	2.048	1.756	-0.293
LA	E1	US-190	2.40	16,000	TLTWO	Tubes	9.505	7.097	-2.408
LA	F15	IR-20	7.20	23,870	TLTWO	Tubes	6.607	2.322	-4.285
TOTAL =			26.40	84,640	AVERAGE =		4.788	3.250	-1.539

Table 28. Construction study projects / annual accident rates by type of channelizing device used.

Project Number		Route	Study Length (miles)	ADT	Type TCP Used	Primary Chan. Device	Before Accs./Mi./10K ADT	During Accs./Mi./10K ADT	Change During vs. Before
ASPHALT CONCRETE DIVIDER									
NC	E9	US-1 SB	1.82	15,000	TLTWO	AC Div.	2.674	4.457	1.783
NC	F4	IR-40	11.70	17,000	TLTWO	AC Div.	2.050	3.415	1.365
MI	F8	IR-94	10.00	18,500	TLTWO	AC Div.	3.886	4.185	0.299
LA	F9	IR-20	8.80	13,530	TLTWO	AC Div.	1.703	1.606	-0.097
MI	A2	IR-94	10.00	29,000	TLTWO	AC Div.	2.884	2.535	-0.350
MI	F6	IR-96	12.00	12,800	TLTWO	AC Div.	5.104	3.062	-2.042
TOTAL =			54.32	105,830	AVERAGE =		3.013	3.182	0.169
CONES AND/OR DRUMS									
WV	D3	IR-64	2.69	19,000	SLC	Drums	1.587	9.522	7.935
MI	C10	IR-96	9.90	24,500	SLC	Drums	4.317	7.935	3.618
UT	C3	IR-15	16.25	4,543	SLC	Drums	3.022	5.768	2.747
FL	C15	IR-295	4.80	20,000	SLC	Cone/Dr ?	4.999	7.604	2.605
LA	C3	IR-10	11.00	24,070	SLC	Drums	1.659	3.094	1.435
KY	G1	IR-75	4.00	23,000	TLTWO	Cones	1.469	2.498	1.029
NC	C17	IR-85	13.07	41,300	SLC	Drums	1.803	2.667	0.864
KY	C4	SR-114	14.40	7,590	SLC	Cone/Dr ?	2.298	3.117	0.819
OH	E1	IR-75	6.99	25,358	SLC	Drums	1.754	2.517	0.763
NC	C3	IR-85	7.35	30,000	SLC	Drums	2.023	2.722	0.699
NC	B7	IR-40	7.80	35,000	SLC	Drums	2.419	2.569	0.150
OR	C8	IR-84	16.89	12,425	SLC	Cones	1.044	1.160	0.116
FL	C16	IR-295	7.52	26,000	SLC	Cone/Dr ?	3.336	3.423	0.086
LA	C4	IR-12	14.80	21,610	SLC	Drums	1.268	1.250	-0.018
NC	B8	IR-95	11.57	20,000	SLC	Drums	1.893	1.854	-0.039
UT	G6	IR-84	10.70	3,845	TLTWO	Drums	3.265	3.019	-0.246
LA	B14	IR-20	6.10	23,470	SLC	Cone/Dr ?	1.133	0.850	-0.283
FL	G5	SR-95	2.80	4,900	TLTWO	Cone/Dr ?	5.173	4.803	-0.369
KY	D7	IR-75	8.00	26,000	SLC	Cone/Dr ?	1.414	0.877	-0.536
AZ	C11	IR-10	14.09	8,000	SLC	Cone/Dr ?	6.881	5.802	-1.079
NC	F1	IR-40	—	—	SLC	Drums	—	—	—
TOTAL =			190.72	400,611	AVERAGE =		0.390	0.310	-0.080

Project Number		Route	Study Length (miles)	ADT	Type TCP Used	Primary Chan. Device	Before Accs./Mi./10K ADT	During Accs./Mi./10K ADT	Change During vs. Before
TEMPORARY CONCRETE BARRIER									
NC	G13	IR-40	3.44	30,000	SLC	TCB	1.535	4.435	2.900
MI	G3	IR-69	6.11	15,500	TLTWO	TCB	1.397	4.239	2.841
AZ	C5	IR-8	6.10	5,900	SLC	TCB	0.939	3.381	2.442
WV	D8	IR-79	4.16	6,200	SLC	TCB	2.657	4.971	2.313
WV	E6	IR-77	2.60	9,300	TLTWO	TCB	2.516	4.193	1.677
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OR	A1	IR-5	7.06	24,200	TLTWO	TCB	0.712	1.780	1.068
OR	C6	IR-84	18.39	5,550	LC/T	TCB	2.053	2.980	0.927
NC	F2	IR-40	16.89	25,000	T/LC	TCB	0.980	1.700	0.720
OR	B4	IR-5	15.52	20,550	LC/T	TCB	0.297	0.787	0.490
AZ	G7	IR-10	3.30	33,000	SLC	TCB	4.506	4.692	0.186
OR	A2	IR-5 NB	13.18	22,550	TLTWO	TCB	0.978	1.043	0.065
MI	D5	IR-196	3.00	11,400	SLC	TCB	0.000	0.000	0.000
AZ	E6	IR-10	2.20	12,000	TLTWO	TCB	2.496	2.304	-0.192
AZ	E2	IR-40	6.20	8,800	SLC	TCB	2.478	2.058	-0.419
WV	E5	IR-64	2.05	27,000	TLTWO	TCB	5.496	2.931	-2.565
UT	A4	IR-15	8.80	5,218	TLTWO	TCB	5.447	2.815	-2.631
UT	A5	IR-80	—	—	T/LC	TCB	—	—	—
TOTAL =			128.93	294,168	AVERAGE =		0.777	0.475	-0.302
TUBES									
LA	F6	IR-59	5.54	12,960	TLTWO	Tubes	3.314	3.615	0.301
LA	F7	IR-20	2.68	27,590	TLTWO	Tubes	1.590	1.877	0.287
KY	F9	WKP	1.70	4,200	TLTWO	Tubes	2.048	1.756	-0.293
LA	E1	US-190	1.19	16,000	TLTWO	Tubes	9.505	7.097	-2.408
LA	F15	IR-20	7.21	23,870	TLTWO	Tubes	6.607	2.322	-4.285
CA	A1	IR-80	N/A	N/A	N/A	Tubes	N/A	N/A	N/A
TOTAL =			18.32	84,640	AVERAGE =		4.788	3.250	-1.539

Estimating Traffic Delays and Road User Costs

Introduction

A quick estimating procedure is presented to allow highway agencies and other analysts to compare the differences in road user costs between SLC and TLTWO traffic control strategies during construction on four-lane divided roadways. As previously mentioned, road user costs are a very essential component of an overall economic assessment of these two types of traffic control strategies. The 2 strategies differ in terms of their implementation costs, duration of construction, and other factors which should be considered when deciding on which strategy to use. When such a comparison is made, the differences in how each strategy affects road user costs on the roadway must also be examined.

This procedure addresses only travel time and vehicle operating costs.

The two main factors that affect road user costs on a primary roadway are the traffic volume demand and roadway capacity at the work zone. Each highway construction project will have a unique set of conditions and constraints that requires individualized analysis and customized solutions. The ideal approach to analyzing road user costs for a construction project would be to use a computer analysis program. Microcomputer-based analysis programs are available which might be useful for this purpose.[7]

The magnitude and duration of the traffic capacity reductions on the highway under construction, coupled with the amount of traffic demand on that highway, determine the appropriate scope and level of effort that a highway agency should expend for the road user cost impact evaluation. In general, the greater the (1) demand volumes (i.e., in urban areas), (2) reduction in capacity on a highway under construction, and (3) duration of the capacity reductions, the greater the scope and level of effort justified in the road user cost impact evaluation.

For major urban highway construction projects in which significant reductions in capacity (i.e., lane closures or total roadway closures) are necessary and traffic demands are high, road user impacts are likely to extend beyond the highway under construction. Therefore, the impact evaluation should be corridor-wide. A major issue in a corridor-wide evaluation is how traffic will reallocate among alternate routes in the corridor. For these kinds of complex issues, it may be necessary to use more complex models with larger data requirements that can simulate the characteristics of the urban environment and attempt to estimate the changes in travel patterns caused by construction.

However, for most rural and suburban highway construction projects, the road user impacts may be restricted to only the highway under construction. Unless high traffic volumes are encountered (over 2,000 vehicles per hour), it is unlikely that significant road user impacts would extend beyond the highway under construction. In these situations, simpler work zone lane closure computer analysis models are all that is likely to be needed to estimate the impacts of various traffic control options being considered.

Researchers recently reviewed the state-of-the-art of microcomputer-based analysis tools that might be useful in evaluating road user cost associated with highway construction projects.[10] The authors concluded that the QUEWZ and FREQ computer models are the simplest and most appropriate models for rural and suburban highway construction projects.

Recognizing that not all highway agencies have immediate access to the QUEWZ and FREQ computer models and there is a need for a quick way to assess road user costs for SLC and TLTWO traffic control strategies on rural and suburban four-lane divided highways, a quick estimating procedure was developed using the QUEWZ model and is presented in this report. The procedure is presented below in graphical form.

The Procedure--

Factors Used in the Procedures

The procedure is developed around only 4 basic pieces of data: (1) normal demand volumes on a roadway; (2) estimated capacity of the work zone; (3) estimated length of the work zone; and (4) the percentage of trucks. In general, road user costs are affected at work zones because of decreased speeds (reflecting the reduced roadway capacity) which affect motorist travel times and vehicle operating costs, and the introduction of speed change cycles as drivers slow down prior to the work zone and then speed up once through. Travel times and vehicle operating costs are dependent on the length of reduced capacity, which explains why the length of work zone is included in the analysis. Finally, vehicle operating, speed change cycle, and travel time costs are significantly different between automobiles and trucks.

Scope of the Procedure

Only road user costs associated with travel on four-lane divided highways have been included in the procedure. Travel time and vehicle operating costs for drivers who divert to alternative routes, and drivers who normally travel the alternative routes, are not included. Separate analysis should be made if there is significant diversion from the primary four-lane divided highway to alternative routes.

Steps in the Analysis Process

The procedure essentially consists of 5 major steps. These steps must be performed for each direction of travel in which a lane is closed. In other words, the procedure would be performed for one direction of travel for a SLC (for the lane closure direction), and for both directions of travel of the TLTWO (for the median crossover traffic as well as the opposite direction). The basic steps in the procedure are:

(1) Estimate the Demand Volumes in a Given Direction of Travel

The first data needed for the analysis is an estimate of the demand volumes expected on the roadway during construction. The units of this data are in hourly volumes. Road user costs at lane closure construction sites on four-lane divided highways for demand volumes less than 200 to 300 vph may be considered negligible and can be ignored. Depending on the scope of the analysis, it may be desirable to estimate road user costs only during peak traffic periods. Under these conditions, it will be necessary to obtain demand (highest) hourly volumes during the daily peak periods and other peak periods when the demand volumes are expected to exceed the roadway capacity during the closure (e.g., weekday peak hours in suburban or metropolitan fringe areas, and holiday or other weekends on Friday and Sunday evenings in rural or recreational areas). The durations of these peak periods would also have to be estimated. These volumes may be obtained from the highway agency traffic planning unit or a similar agency responsible for taking traffic counts. If not available, field counts may be taken or projected to current year from older existing counts.

Under other conditions, the scope of the analysis may require that traffic demands during both peak and off-peak conditions be examined. For simplicity, it is recommended that the time-of-day distribution of traffic be represented by two or three periods of constant demand. An example of a simplified representation of traffic demand throughout a representative day is shown in figure 8. Here, the dashed line represents the actual hourly demand volumes at a given location, while the solid line illustrates a possible simplified demand function. For analysis purposes, an off-peak hourly flow of 1,000 vph is assumed to exist for a total of 10 hours (8 a.m. to 4 p.m plus 7 to 9 p.m.), while a peak period volume of 1,500 vph is assumed to occur for 3 hours (4 p.m. to 7 p.m.). Of course, other simplifications are possible, and it would the analyst's discretion to decide how to best represent the demands throughout the day (depending on the scope of the analysis).

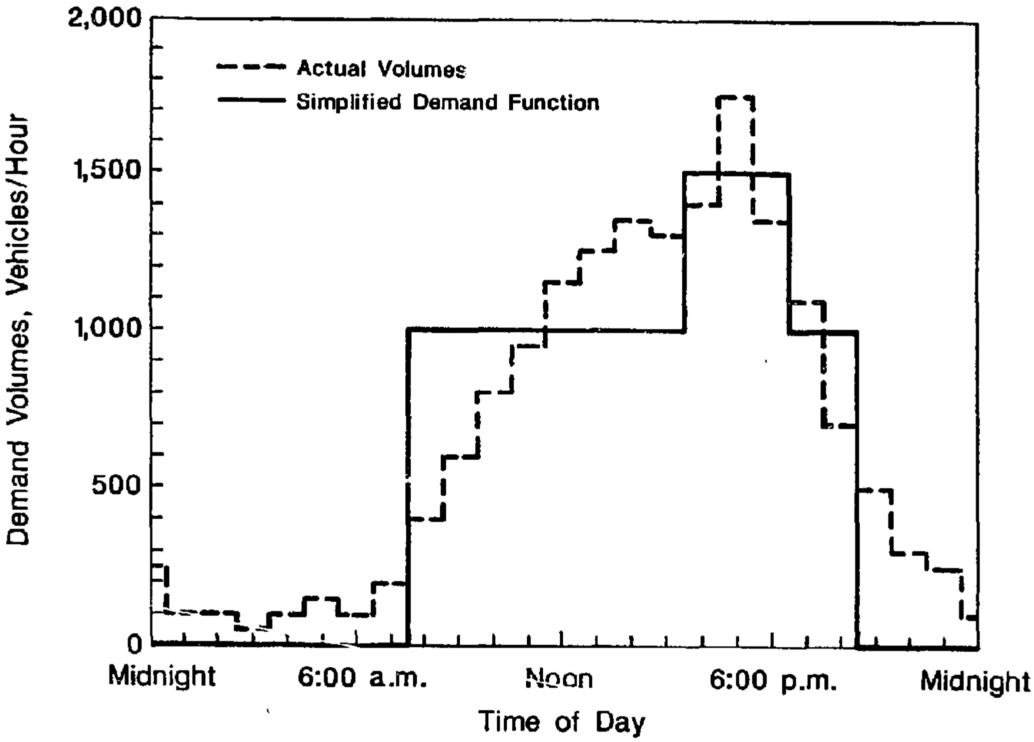

Figure 8. Sample representative traffic demand on a typical weekday.

It should be emphasized that the accuracy of the estimate of road user costs on the roadway is heavily dependent upon two factors: (1) the accuracy of the estimate of demand hourly volumes (the highest hourly traffic volumes you anticipate); and (2) the accuracy of the estimate of roadway capacity anticipated during the construction. The estimate of road user costs is only as good as the estimates of demand volumes and capacity.

(2) Estimate the Work Zone Capacity

The second factor needed for the analysis is an estimate of the capacities in the work zone. For SLCs, capacity in the closure direction must be estimated. For TLTWO, capacities must be estimated in the direction of the crossover and for the opposite direction (where a lane closure is also implemented). Work zone capacities are very difficult to estimate. As discussed in the introduction and field study analysis section of this report, the existing database is fairly small, and the wide variety of factors that influence capacity have not been adequately studied in sufficient detail.

The research reported in this report suggests that the capacity of a SLC is about 1,800 vph. However, there are circumstances that can significantly reduce the maximum traffic flow to as low as 950 vph. Therefore, it is difficult to identify a single capacity flow value to select for all conditions. If there are no obstructions (such as narrow bridges or high volume entrance ramps, or other construction activities within the work zone, including construction work itself, that would adversely affect traffic flow), then 1,800 vph is a reasonable value to use. However, if there are obstructions and/or other influencing activities, then the analyst must use a capacity estimate lower than 1,800 vph.

The procedure is flexible and permits different work zone capacities to be used in the analysis. One can quickly examine a range of capacities if desired to obtain a sensitivity analysis of the effects of different capacities upon the work zone being evaluated.

The research reported within this report also suggests that maximum TLTWO capacities are approximately 1,500 to 1,550 vph in the closure direction, and about 1,800 vph in the opposite direction. But these values may be reduced if there are narrow bridges in the TLTWO section, the geometrics of the median crossover are not sufficient or there are other obstructions or activities within the TLTWO section that adversely affect traffic flow. Normally traffic will flow within a TLTWO somewhat freely because it is away from the actual construction work activities.

Selection of appropriate capacities should take into consideration the length of work zone, method of closing the lane and separating opposing traffic, and the width of bridges and the traveled way (pavement and shoulders). The above discussion is provided to assist in the selection of a realistic preliminary capacity value. More definitive recommendations can be made when a better data base is obtained.

(3) Determine Appropriate Unit Cost Factors

Figure 9 was developed using the QUEWZ3 computer model and presents the relationship among demand volumes, capacities and unit cost factors for work zones using 1987 dollars and an 8 percent truck factor where demands do not exceed capacity. Figure 9a is an enlargement of the bottom portion of figure 9. These figures are appropriate for both the SLC and TLTWO strategy analyses. The curves represent additional road user costs generated through the lane closure section. No congestion is anticipated to develop upstream of the lane closure, although slight congestion may occur when the demand volumes approach capacity. For the TLTWO strategy, cost factors based on the estimated capacity and demand for that direction must be determined for each direction of travel, while the SLC strategy involves only one direction. The resulting factor is a cost per mile of work zone per hour. These cost factors are

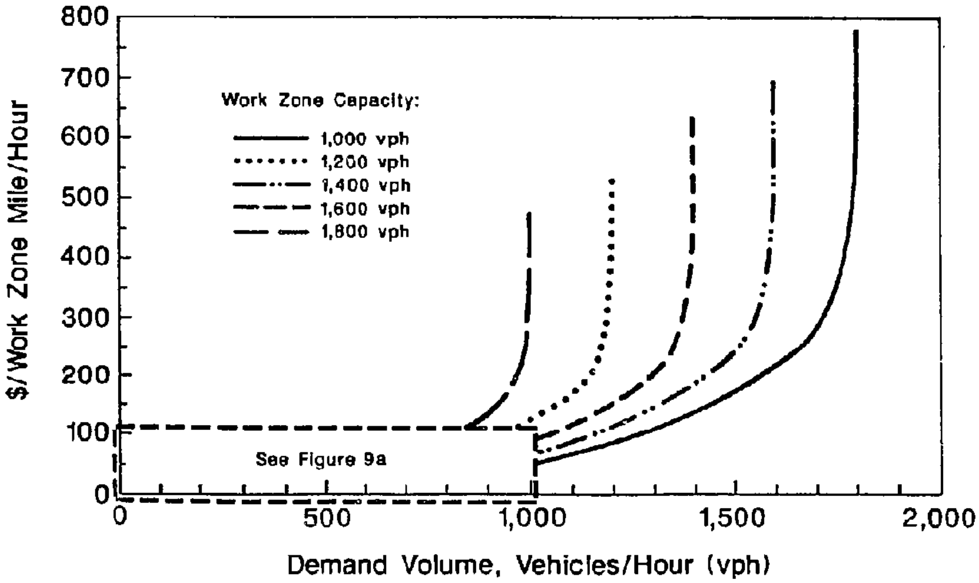

Figure 9. Road user costs for non-congested conditions (demand volumes 1,000 to 2,000 vehicles/hour).

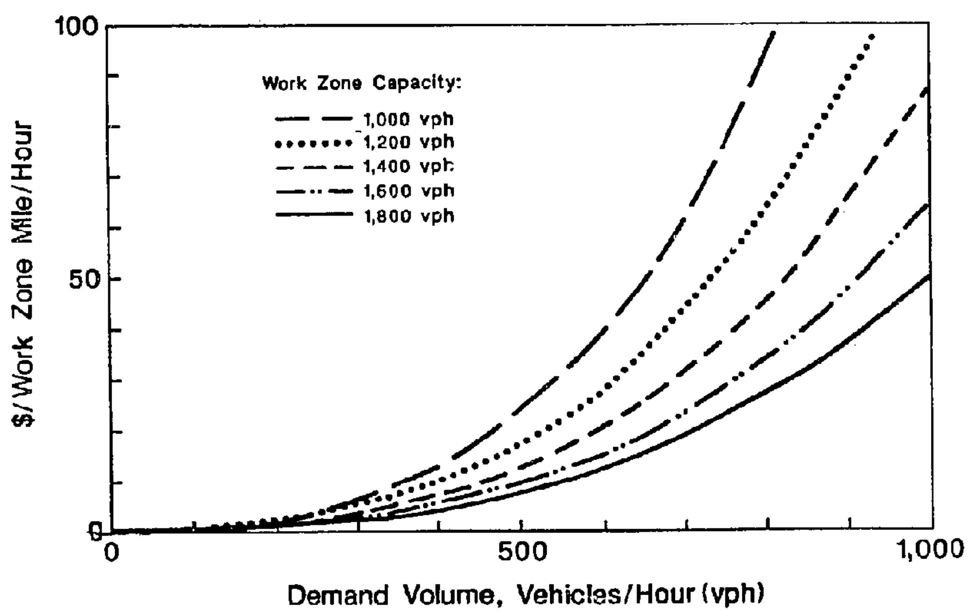

Figure 9a. Road user costs for non-congested conditions (demand volumes 0 to 1,000 vehicles/hour).

then multiplied by thelength of the work zone and the number of hours that the demand volume is estimated to be at that constant value in order to determine the total road user costs for that time period.

If <u>demands exceed capacity</u>, congestion develops upstream of the work zone. This congestion generates large amounts of delays and, as a result, overshadows the effects of the other components (vehicle operating and speed change cycling costs, and travel time costs <u>through</u> the lane closure section). As an estimate of costs during congested conditions, figure 10 was developed using the QUEWZ3 computer model. It presents the relationship between the average length of queue during an hour to the hourly road user costs. There are different lines on this figure for all levels of capacity, but they are so close together that the graph appears to be only one line with some variation in width. This further illustrates how the delay component associated with the queue overrides the other components in the analysis.

An average queue length must be estimated for each hour that the traffic demand exceeds the capacity and for subsequent hours until the queue clears. The amount that traffic demand exceeds capacity is assumed to queue upstream of the lane closure of the work zone. To estimate the average queue length, one begins with the first hour that demand exceeds capacity. At the end of the first hour, the excess demand (the number of vehicles that demand exceeded capacity) is converted to a queue length using the following relationship: (7)

$$QL(hour1) = \frac{V \times vl}{n \times 5,280}$$

where

QL(hour1) = queue length at the end of the first hour of congestion, miles

V = excess demand volume after the first hour of congestion, veh

vl = average spacing in feet between vehicles in a queue (use 40)

n = number of lanes upstream of the lane closure

The average queue length during the first hour AQL(hour1) of congestion, is:

$$AQL(hour1) = QL(hour1)/2.$$

The second hour's excess demand is added to that of the first, and the queue length computed in a similar fashion as before. The average queue length during the second hour, AQL(hour2), would be:

$$AQL(hour2) = [QL(hour1) + QL(hour2)]/2.$$

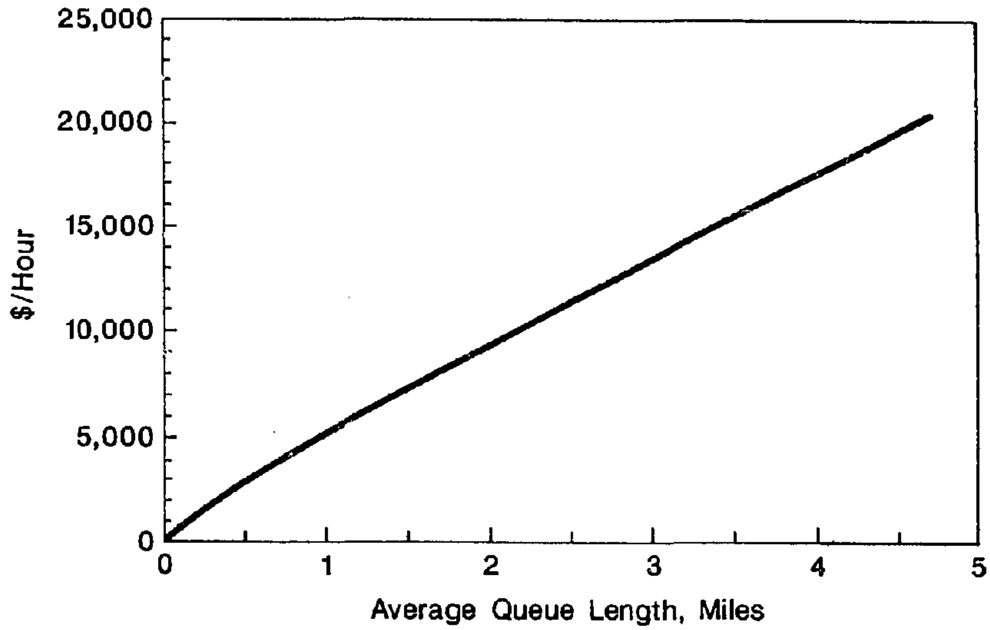

Figure 10. Road user costs for congested conditions (based on average queue length).

Computations would continue in this fashion until demands drop to below capacity. During the succeeding hours the number of vehicles in the queue would be reduced hour by hour by the amount that demand is then less than capacity. Average queue lengths would be computed in the same fashion until the number of vehicles in the queue drops to zero (the queue clears). An average queue length would thus be estimated for each hour of congestion. Figure 5 would be used to determine road user costs for each of these hours. The road user costs for each hour would then be summed to produce the total road user costs on the roadway for the periods when congestion would be anticipated.

(4) Adjust Costs for Different Truck Percentages

An adjustment should be made to the calculations to account for the effect that different proportions of truck traffic have upon road user costs. Figures 11 and 12 were developed using a default truck percentage in the traffic stream of 8 percent. For situations where truck traffic differs by this amount considerably, adjustments must be made.

A series of QUEWZ3 runs were made, holding traffic demands and capacities constant but varying the percentage of trucks in the ratios, at least for those ratios greater than 0.5 (cost values for v/c ratios below 0.5 were too small to accurately determine the effect of trucks). For lack of better estimates, it is suggested that these values be used for v/c ratios less than 0.5 also.

	Percentage of Trucks						
	2	4	6	8	10	12	14
Adjustment Factor	0.90	0.94	0.97	1.00	1.03	1.07	1.10

In general, it appears that a 2 percent difference in truck traffic (from the default value of 8 percent) results in a 3 to 4 percent change in road user costs. Once an appropriate adjustment factor has been established, it is multiplied by the unit or daily costs (whichever is preferred, but not both) to determine the road user costs adjusted for trucks.

(5) Compute Additional Road User Costs

Unit cost factors for uncongested conditions are expressed as dollars per hour per work zone mile. The unit cost factor must, therefore, be multiplied by the length of the work zone being evaluated. Also, the factor must be multiplied by the number of hours that the unit cost factor is assumed constant. There may be several unit cost factors used for various times of the day, depending on how the analyst chooses to represent the daily distribution of traffic demand. The additional road user costs computed for each time period are summed to compute the total additional (uncongested) road user costs generated each day. In equation form:

$$TARUC_{un} = (UNC_1 \times WZL \times T_1) + (UNC_2 \times WZL \times T_2) + (UNC_3 \times WZL \times T_3) + \ldots$$

$TARUC_{un}$ = Total additional road user costs during uncongested conditions
UNC_i = Unit additional road user cost during time period i ($/hr/mi)
WZL = Length of work zone (miles)
T_i = Duration of time period i (during which demand volumes and unit cost factors are assumed to be constant)

If congestion develops during a period of time, the cost values computed from figure 11 directly represent the effect of the queue upon road user costs. These cost values are determined hour by hour during the time that the queue is present. They are then

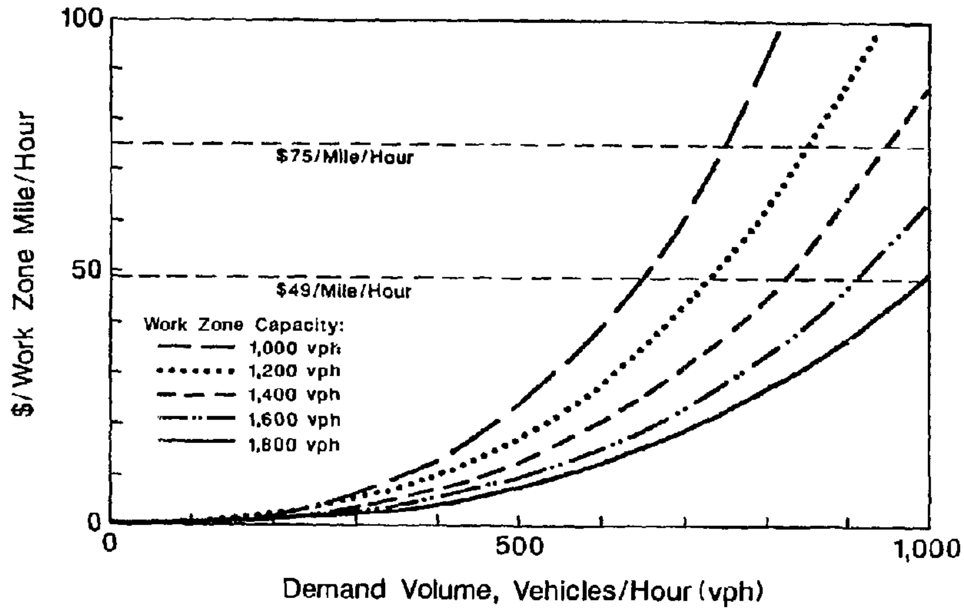

Figure 11. Road user costs during non-congested conditions for example problem.

simply summed to determine the total additional road user costs during congestion. These costs are then added to the total additional road user costs during uncongested conditions to determine the total daily additional road user costs at the work zone.

Example of the Procedure:

As an example of this procedure, assume that both SLC and TLTWO traffic control strategies are being contemplated for a four-lane divided highway work zone. It has been estimated that weekday traffic volumes per direction during the peak periods are as shown below. To simplify the analysis, traffic volumes during non-congested conditions are assumed to be represented as an average demand volume of 1,000 vph for a 10 hour off-peak period. After that, the volume is negligible. The work zone will be approximately 3.0 miles long if the single-lane closure strategy is used. If the TLTWO strategy is used, the work zone will be 4.0 miles. There are 6% trucks on the roadway. Based on the conditions at the site, it is estimated that the capacity flow if the single-lane closure strategy is used will be 1,800 vph. If the TLTWO strategy is used, it is expected that the maximum traffic flows will be 1,500 vph in the crossover direction and 1,800 vph in the opposite direction. The problem is to determine the road user costs when the lane closure or the crossover is in Direction in the opposite direction. The problem is to determine the road user costs when the lane closure or the crossover is in Direction 1. Table 29 shows an example of typical hourly traffic volumes through a work zone that may be used to illustrate our problem.

Table 29. Example hourly traffic volumes through the work zone.

	Direction 1	Direction 2
6- 7am	200	1,400
7- 8am	400	2,000
8- 9am	700	1,600
9-10am	750	900
10-11am	800	800
3- 4pm	1,300	800
4- 5pm	1,500	900
5- 6pm	1,900	950
6- 7pm	1,650	600
7- 8pm	800	400
8- 9pm	600	500
9-10pm	500	450

For SLC Strategy--

(1) Estimated Capacity = 1,800 vph in the closure direction.

(2) For off-peak periods (non-congested conditions), demand volume = 1,000 vph, unit cost factor is equal to $49/mile/hour of lane closure in Direction 1 (figure 11).

(3) For peak periods (congested conditions), table 30 shows the number of vehicles that would be delayed.

Table 30. Example of number of vehicles delayed for SLC.

	Volume Direction 1	Capacity	Excess Vehicles	Accum. Vehicles
6- 7am	200	1,800	0	0
7- 8am	400	1,800	0	0
8- 9am	700	1,800	0	0
9-10am	750	1,800	0	0
10-11am	800	1,800	0	0
3- 4pm	1,300	1,800	0	0
4- 5pm	1,500	1,800	0	0
5- 6pm	1,900	1,800	100	100
6- 7pm	1,650	1,800	(150)	0
7- 8pm	800	1,800	(1,000)	0
8- 9pm	600	1,800	(1,200)	0

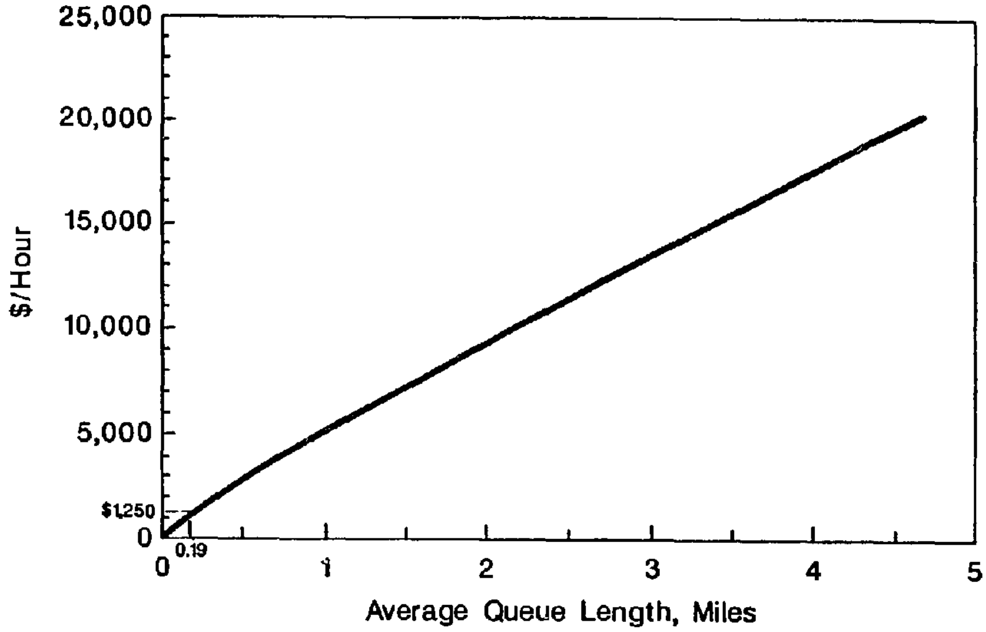

Figure 12. Road user costs during congested conditions for example problem (single lane closure strategy).

(Note: In table 30, Direction 1 is the off-peak direction in the a.m. Hence, these volumes are accounted for in the equivalent off-peak unit factor determined in Step 2.)

Queue length (hour ending at 5pm)	=		= 0.0 mi
Queue length (hour ending at 6pm)	=	(100)(40)/(2)(5280)	= 0.38mi
Queue length (hour ending at 7pm)	=		= 0.0 mi
Queue length (hour ending at 8pm)	=		= 0.0 mi

Average queue length (hour ending at 5pm) = 0.0 mi
Average queue length (hour ending at 6pm) = 0.19 mi
Average queue length (hour ending at 7pm) = 0.19 mi
Average queue length (hour ending at 8pm) = 0.0 mi

Avg. congested road user cost (hr ending at 5pm) = $ 0
Avg. congested road user cost (hr ending at 6pm) = $ 1,250 (fig.12)
Avg. congested road user cost (hr ending at 7pm) = $ 1,250 (fig.12)
Avg. congested road user cost (hr ending at 8pm) = $ 0

Total road user cost during congestion = <u>$2,500/day</u>

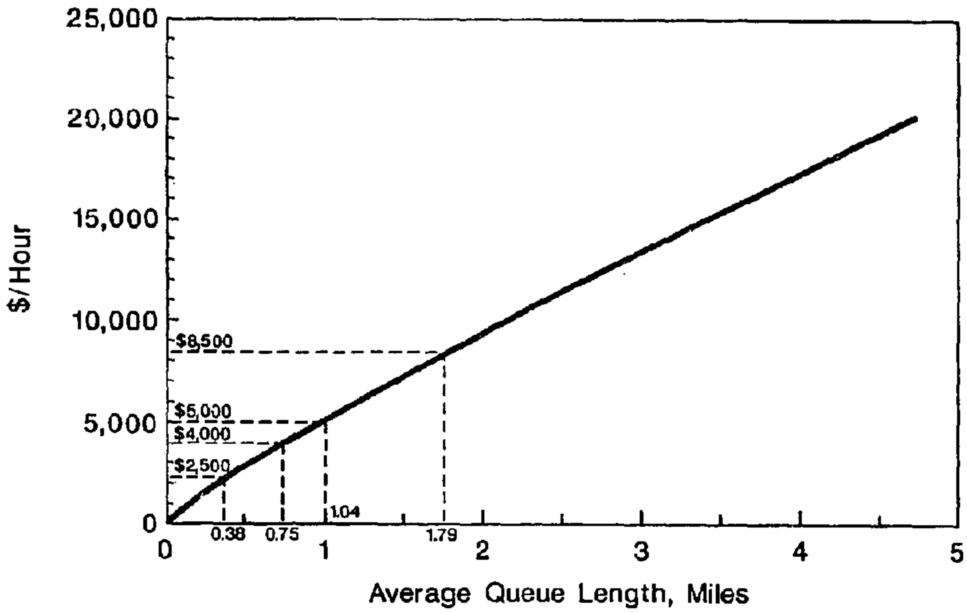

Figure 13. Road user costs during congested conditions for example problem (crossover strategy).

Total road user cost during non-congested conditions ($49/mi/hr x 3 mi x 10 hrs)	= <u>$1,470/day</u>
UNADJUSTED TOTAL ROAD USER COST	= <u>$3,970/day</u>

(4) Truck adjustment factor = 0.97 for 6% trucks

TOTAL ROAD USER COST = $3,970 X 0.97 = $3,850/day

For TLTWO Strategy--

(1) Estimated Capacity = 1,500 vph in the crossover direction
= 1,800 vph in the opposite direction

(2) For off-peak periods (non-congested conditions), demand = 1,000 vph, unit cost factor is $75/mi/hr in the crossover direction and $49/mi/hr in the opposite direction (figure 11)

(3) Table 31 shows the number of vehicles delayed for TLTWO in direction 1.

Table 31. Example of number of vehicles delayed for TLTWO in direction 1.

	Volume Direction 1	Capacity	Excess Vehicles	Accum. Vehicles
3- 4pm	1,300	1,500	0	0
4- 5pm	1,500	1,500	0	0
5- 6pm	1,900	1,500	400	400
6- 7pm	1,650	1,500	150	550
7- 8pm	800	1,500	(700)	0
8- 9pm	600	1,500	(900)	0
9-10pm	500	1,500	(1,000)	0

Queue length (hour ending at 5pm) = = 0.0 mi
Queue length (hour ending at 6pm) = (400)(40)/(2)(5280) = 1.50mi
Queue length (hour ending at 7pm) = (550)(40)/(2)(5280 = 2.08mi
Queue length (hour ending at 8pm) = = 0.0 mi
Queue length (hour ending at 9pm) = = 0.0 mi

Average queue length (hour ending at 5pm) = 0.0 mi
Average queue length (hour ending at 6pm) = 0.75 mi
Average queue length (hour ending at 7pm) = 1.79 mi
Average queue length (hour ending at 8pm) = 1.04 mi
Average queue length (hour ending at 9pm) = 0.0 mi

Avg. congested road user cost (hr ending at 5pm) = $ 0
Avg. congested road user cost (hr ending at 6pm) = $4,000 (fig. 13)
Avg. congested road user cost (hr ending at 7pm) = $8,500 (fig. 13)
Avg. congested road user cost (hr ending at 8pm) = $5,000 (fig. 13)
Avg. congested road user cost (hr ending at 9pm) = $ 0

Total road user cost during congestion (direction 1) = <u>$17,500/day</u>

(4) Table 32 shows the number of vehicles delayed in direction 2.

Table 32. Example of number of vehicles delayed for TLTWO in direction 2.

	Volume Direction 2	Capacity	Excess Vehicles	Accum. Vehicles
6- 7am	1,400	1,800	0	0
7- 8am	2,000	1,800	200	200
8- 9am	1,600	1,800	0	0
9-10am	900	1,800	0	0
10-11am	800	1,800	0	0

Queue length (hour ending at 8am) = (200)(40)/(2)(5280) = 0.75mi
Queue length (hour ending at 9am) = 0.00mi

Average queue length (hour ending at 8am) = 0.38 mi
Average queue length (hour ending at 9am) = 0.38 mi

Average road user cost (hour ending at 8am) = $ 2,500 (figure 13)
Average road user cost (hour ending at 9am) = $ 2,500 (figure 13)

Total road user cost during congestion (direction 2) = $ 5,000/day

(5) Total road user cost during non-congested conditions ($49/mi/hr x 4 mi x 10 hrs) + ($75/mi/hr x 4 mi x 10 hrs) = $ 4,960/day

UNADJUSTED TOTAL ADDITIONAL ROAD USER COST
$17,500 + $5,000 + $4,960 = $27,460/day

(6) Truck adjustment = 0.97 for 6% trucks

TOTAL ADDITIONAL ROAD USER COST
$27,460 X 0.97 = $26,640

Thus, the lane closure strategy will increase road user costs by about $ 3,850 per weekday, when the lane closure is in direction 1 compared to the TLTWO strategy which will increase costs approximately $26,640 per weekday when the crossover is in direction 1. The next part of the analysis would be to evaluate the weekday road user costs when the closure or crossover is in direction 2. Then the procedure is repeated to evaluate weekend conditions.

The example assumes that for SLC there is a lane closure in one direction only, in comparison with the TLTWO alternative. If the construction project sequence anticipates concurrent lane closures both directions for the SLC, these road user costs must also be considered in the comparative of the 2 strategies.

VI. SUMMARY OF RESULTS

There are many findings from this research conducted to study the construction costs and safety impacts associated with work zones involving SLC and TLTWO on rural four-lane divided highways.

The primary finding in this research is that there are many variables associated with construction work zones that limit the development of guidelines for selecting the most cost-effective traffic control strategy.

The study found accident rates were not significantly different between the 2 traffic control strategies. Therefore, the selection of the traffic control strategy is primarily based on the type of construction. If traffic congestion is expected to be a problem, the construction and traffic delay costs should be studied before selecting the control strategy.

The original scope of the research study anticipated that the participating States would select sufficient projects within few enough construction categories that would provide large samples that could be statistically analyzed and compared. The States provided a wide variety of candidate projects (109) from which to select, but it was necessary to consider 7 realistic construction classifications when the final study projects were selected in order to obtain meaningful results. Therefore, the study encompassed a broader scope than originally envisioned.

In addition it was anticipated that traffic delays would occur within projects selected for study. However, only 3 construction study projects approached lane closure capacity, and delays were not encountered during the field studies of most of the project work zones. Consequently the study of construction and safety impacts of the 51 construction projects were somewhat divorced from the field traffic studies conducted to measure delays and develop capacity range limits for work zones on four-lane divided highways.

As a result of this research study much knowledge was gained and documented that should assist professionals in highway agencies and construction in data collection procedures and selecting more cost-effective methods for traffic control in work zones for rural four-lane divided highways.

Accident Analysis

The accident rates for each project were determined for the before construction and during construction periods. It was found that there was no statistical difference in the accident rates for SLC versus TLTWO over the time periods covered for 49 construction projects. There was no significant difference found in total accident rates before versus during construction for all projects, but the fatal plus injury accidents had a significant increase during construction for both traffic control strategies. In the analysis of accident rate change, it was found the SLC projects tend to show more of an increase, and TLTWO projects more of a decrease in accident rates during construction as shown in table 15.

Selecting the Most Cost-Effective Strategy

Based on the research conducted, the following guidelines are offered considering the various elements affecting traffic control strategy selection of either SLC or TLTWO for construction projects.

Type of construction and traffic control strategy must be carefully considered in conjunction with each other for major improvements to, and maintenance of, existing highways. This research study analyzed the 7 most common types of rural four-lane divided highway construction projects in 11 different States. The following factors were carefully considered in the analysis to arrive at general conclusions: project design history, total construction and traffic control costs, alternate traffic control strategies and estimated costs, nature of work performed during construction, significant changes during construction, traffic accidents and road user costs.

It is most important to recognize that no 2 construction projects that are similar in type of construction are necessarily comparable. Each project will have variations in work performed to take care of the improvement needs for a particular highway. The 51 projects that were studied in this research were grouped into 7 classifications. Some of the projects could have been placed in different classificaions for comparison purposes, but the conclusions reached are believed to be reasonable for the purposes of the research performed.

The general findings, shown in table 33, are based on the data collected and analysis performed on rural four-lane divided highway construction projects where traffic volumes were between 10,000 and 30,000 vehicles per day. The information shown is not to be considered a substitute for the need for sound engineering judgement and the careful consideration of all alternatives in the selection of the most cost-effective traffic control strategy for a given project. The research did not study or consider the need for detouring traffic on alternate routes, which obviously is a third alternative that should always be investigated for feasibility.

Estimating Traffic Control Costs

It was not possible to develop unit prices for traffic control items of work because of the diversity of bidding practices in the various States. The basis of payment for each study project shown

Table 33. Suggested traffic control strategies by construction type.

Type of Construction	Traffic Control Strategy
Concrete Pavement Recycling/Overlay	TLTWO
Concrete Pavement Restoration	*SLC (Analysis)
Asphalt Concrete Pavement Overlay	SLC
Bridge Deck Overlay	SLC
Bridge Deck Replacement/Widening	TLTWO
Reconstruction	TLTWO
New Interchange/Construction	Analysis

* Road User Cost Analysis should be performed for work delays

in table 11 reflects the variety of methods of bidding for the 51 study projects that made it difficult to develop ranges of unit costs for traffic control work items. A number of common bid items and cost ranges are presented in table 12 for the States.

To determine costs a range of prices for traffic control as related to total construction costs were developed for the seven types of construction. These costs are presented in table 9.

<u>Median Crossover Features and Costs</u>

When using the TLTWO traffic control strategy, it was also found desirable to develop a summary of costs for median crossovers that must be constructed when TLTWO is specified. There is a wide variation in costs ranging from $7,111 to $70,605 as presented in tables 13 and 14 for median crossovers. This variation is because of a number of features including geometric design, pavement design, median width, bidding practices, etc. However, this information can serve as a guide for ranges of costs that may be used in considering TLTWO strategies.

<u>Average Construction Costs per Unit of Time and Distance</u>

From the construction study costs it was possible to develop a summary of costs per day and costs per mile for each project by type of construction that may be used for estimating costs. They are presented in table 36. An average cost per unit of time and distance is also presented for each type of construction. These estimates should be used with discretion because the <u>unit costs are per calendar day (not working days) and include the entire construction contract period</u>. There is also a wide range of construction costs within any one type of construction because ofthe nature of scope of work included within each project.

Table 34. Study project construction costs per unit length / time.

Project Number		Route	Project Length (miles)	ADT	Type TCP Used	Total Contract Days *	Avg. Days /Mile	Total Const. Cost ($)	Average Total Cost ($) per Mile	Average Total Cost ($) per Day*	TCP Const. Cost ($)	Average TCP Cost ($) per Mile	Average TCP Cost ($) per Day*	Comments
(A) Concrete Pavement Recycling / Overlay (6 Projects)														
CA	A1	IR-80	6.50	21,600	SLC	554	85	13,295,635	2,045,482	23,999	1,142,300	175,738	2,062	
MI	A2	IR-94	5.80	29,000	TLTWO	189	33	7,968,964	1,373,959	42,164	892,065	153,804	4,720	
OR	A1	IR-5	7.04	24,200	TLTWO	787	112	12,012,163	1,706,273	15,263	829,722	117,858	1,054	
OR	A2	IR-5 NB	13.18	22,550	TLTWO	949	72	9,940,549	754,215	10,475	366,308	27,793	386	
UT	A4	IR-15	8.77	5,218	TLTWO	496	57	11,640,004	1,327,404	23,468	1,234,783	140,812	2,489	
UT	A5	IR-80	4.87	12,860	T/LC	462	95	11,570,513	2,375,388	25,044	1,195,715	245,476	2,588	Raise Highway Grade
			6.60	18,576		498	76	11,297,456	1,766,701	25,988	1,058,917	166,738	2,583	(A) Classification Average (Excluding OR A2)
(B) Concrete Pavement Restoration (5 Projects)														
LA	B14	IR-20	5.65	23,470	SLC	73	13	699,782	123,855	9,586	15,000	2,655	205	
NC	B7	IR-40	5.82	35,000	SLC	537	92	4,056,619	697,133	7,554	235,927	40,544	439	Iowa Weave TCP
NC	B8	IR-95	10.05	20,000	SLC	615	61	4,901,963	487,855	7,971	216,345	21,531	352	Iowa Weave TCP
OH	B1	IR-75	5.02	25,358	SLC	163	32	3,615,648	720,823	22,182	299,935	59,796	1,840	
OR	B4	IR-5	15.52	20,550	LC/T	493	32	9,186,788	591,932	18,634	562,754	36,260	1,141	
			8.41	24,876		376	46	4,492,160	524,320	13,185	265,992	32,157	796	(B) Classification Average
(C) Asphalt Concrete Pavement Overlay (13 Projects)														
AZ	C5	IR-8	5.13	5,900	SLC	186	36	2,222,615	433,258	11,950	247,029	48,154	1,328	
AZ	C11	IR-10	12.10	8,000	SLC	257	21	3,011,793	248,991	11,719	75,711	6,259	295	
FL	C15	IR-295	4.77	20,000	SLC	356	75	1,865,670	391,044	5,241	137,951	28,894	387	
FL	C16	IR-295	7.52	26,000	SLC	425	57	2,466,210	327,866	5,803	160,599	21,351	378	
KY	C4	SR-114	12.50	7,590	SLC	448	36	7,602,570	608,206	16,970	199,094	15,928	444	
LA	C3	IR-10	8.96	24,070	SLC	470	52	3,588,713	400,660	7,636	52,500	5,861	112	
LA	C4	IR-12	12.86	21,610	SLC	171	13	1,294,622	100,655	7,571	35,000	2,721	205	
MI	C10	IR-96	5.88	24,500	SLC	317	54	1,643,603	279,524	5,185	38,042	6,470	120	
NC	C3	IR-85	6.00	30,000	SLC	478	80	3,437,750	572,577	7,192	356,388	59,358	746	Iowa Weave TCP
NC	C17	IR-85	11.82	41,300	SLC	502	42	2,607,689	220,617	5,195	155,501	13,156	310	
OR	C6	IR-84	18.39	5,550	LC/T	185	10	6,824,651	371,107	36,890	568,358	30,906	3,072	
OR	C8	IR-84	16.89	12,425	SLC	137	8	366,192	21,681	2,673	13,370	792	98	
UT	C3	IR-15	15.34	4,543	SLC	74	5	2,813,652	183,371	38,022	82,641	5,386	1,117	
			10.63	17,807		308	38	3,057,364	319,966	12,465	163,237	18,864	662	(C) Classification Average
(D) Bridge Deck Overlay (4 Projects)														
KY	D7	IR-75	0.22	26,000	SLC	236	1,083	493,862	2,265,422	2,093	19,500	89,450	83	
MI	D5	IR-196	0.08	11,400	SLC	101	1,232	520,432	6,346,732	5,153	122,408	1,492,780	1,212	
WV	D3	IR-64	0.69	19,000	SLC	21	30	174,585	253,022	8,314	19,978	28,954	951	
WV	D8	IR-79	0.16	6,200	SLC	522	3,263	1,220,779	7,629,869	2,339	18,417	115,106	35	
			0.29	15,650		220	1,402	602,415	4,123,761	4,474	45,076	431,572	570	(D) Classification Average

* "Contract Days" refer to Calendar days of contract duration not Working Days.

Table 34. Study project construction costs per unit length / time. (continued).

Project Number		Route	Project Length (miles)	ADT	Type TCP Used	Total Contract Days *	Avg. Days /Mile	Total Const. Cost ($)	Average Total Cost ($) per Mile	Average Total Cost ($) per Day*	TCP Const. Cost ($)	Average TCP Cost ($) per Mile	Average TCP Cost ($) per Day*	Comments
(E) Bridge Deck Replacement / Widening (6 Projects)														
AZ	E2	IR-40	4.19	8,800	SLC	395	94	2,558,259	610,563	6,477	253,094	60,404	641	Bid TLTWO; SLC per C.O.
AZ	E6	IR-10	0.20	12,000	TLTWO	232	1,140	1,681,428	8,262,544	7,248	357,135	1,754,963	1,539	
LA	E1	US-190	1.19	16,000	TLTWO	979	823	15,020,322	12,622,119	15,343	544,540	457,597	556	Incomplete Final Costs
NC	E9	US-1 SB	0.10	15,000	TLTWO	599	5,760	879,999	8,461,529	1,469	71,368	686,231	119	Design Alternate TCP Estimated Costs
WV	E5	IR-64	0.89	27,000	TLTWO	505	570	2,567,684	2,898,063	5,085	709,449	800,733	1,405	Incomplete Final Costs
WV	E6	IR-77	0.60	9,300	TLTWO	382	639	1,041,904	1,742,314	2,727	315,922	528,298	827	
			1.41	14,620		499	653	4,573,919	5,227,121	7,376	436,028	720,399	994	**(E) Classification Average (Excluding NC E6)**
(F) Reconstruction (11 Projects)														
KY	F9	WKP	1.70	4,200	TLTWO	343	202	1,348,658	793,328	3,932	172,161	101,271	502	Existing TLTWO/Landslide Repair
LA	F6	IR-59	5.54	12,980	TLTWO	1,032	186	10,649,517	1,923,337	10,319	900,438	162,622	873	Incomplete Final Costs
LA	F7	IR-20	2.68	27,590	TLTWO	500	186	5,048,848	1,883,196	10,098	698,387	260,495	1,397	
LA	F9	IR-20	6.78	13,530	TLTWO	645	95	10,111,189	1,491,326	15,676	887,875	130,955	1,377	
LA	F15	IR-20	7.21	23,870	TLTWO	777	108	11,947,245	1,657,728	15,376	1,040,073	144,314	1,339	
MI	F6	IR-96	8.20	12,600	TLTWO	241	29	8,304,603	1,012,756	34,459	394,681	48,132	1,638	
MI	F8	IR-94	5.97	18,500	TLTWO	394	66	7,638,414	1,279,466	19,387	406,969	68,169	1,033	
NC	F1	IR-40	18.43	15,000	SLC	989	54	9,135,648	495,668	9,237	977,682	53,046	989	
NC	F2	IR-40	14.23	25,000	T/LC	926	65	9,523,144	669,042	10,284	934,016	65,619	1,009	
NC	F4	IR-40	8.96	17,000	TLTWO	703	79	6,416,317	716,507	9,127	1,112,589	124,242	1,583	Incomplete Final Costs
NC	F5	IR-77	9.23	32,000	SLC	484	52	5,472,109	592,990	11,306	1,302,858	141,185	2,692	Incomplete Final Costs
			8.08	18,406		639	102	7,781,427	1,137,758	13,564	802,521	118,186	1,312	**(F) Classification Average**
(G) New / Interchange Construction (6 Projects)														
AZ	G7	IR-10	2.11	33,000	SLC	357	169	3,085,206	N/A	N/A	375,802	N/A	N/A	Interchange Construction
FL	G5	SR-95	3.02	4,900	TLTWO	568	188	5,610,988	N/A	N/A	151,636	N/A	N/A	Addition of two lanes
KY	G1	IR-75	0.40	23,000	TLTWO	254	638	2,409,566	N/A	N/A	122,040	N/A	N/A	Interchange Reconstruction
MI	G3	IR-69	2.02	15,500	TLTWO	1,190	589	15,976,716	N/A	N/A	296,642	N/A	N/A	Bid SLC; TLTWO Per C. O. / Intge Const. on U.S. 127
NC	G13	IR-40	2.70	30,000	SLC	689	255	5,892,592	N/A	N/A	512,974	N/A	N/A	Partial Interchange Construction
UT	G6	IR-84	14.15	3,845	TLTWO	1,092	77	21,346,357	N/A	N/A	749,244	N/A	N/A	Addition of two lanes
			4.07	18,374		692	319	9,053,571	N/A	N/A	368,056	N/A	N/A	**(G) Classification Average**

* "Contract Days" refer to Calendar days of contract duration not Working Days.

The various costs and ranges of traffic control elements developed through this research study should provide improved tools for transportation professionals to use in considering design alternative costs for SLC and TLTWO traffic control strategies for proposed construction projects.

Traffic Studies and Road User Costs

Field traffic studies were conducted at 25 construction project sites in 11 States where lane closures were measured for traffic delays, but definitive capacities were not determined because of the wide range of work zone characteristics encountered. It was concluded from the research that TLTWO lane closures in the direction of the median crossovers have capacities during saturated flow in the range of 1,500 to 1,550 vph, with a capacity of approximately 1,800 in the opposite direction, while the SLC capacity is about 1,800. These values may also be reduced because of geometric restrictions or construction activities within a work zone.

A quick estimating procedure to estimate road user costs for SLC and TLTWO was developed and included within the research report, based on findings from field studies and computer models including QUEWZ. The vehicle delay procedure involves 4 basic items: normal traffic demand volumes, estimated capacity through the work zone, length of work zone and the percentage of trucks. This procedure enables preliminary analysis of both traffic control strategies to determine road user cost estimates in conjunction with use of either strategy for proposed construction projects.

Other Research Findings

Several procedures were developed and are documented within this report for possible reference and use by States and other research agencies in the collection of construction project cost data, strategies for monitoring construction progress, accident data and field measure delay in work zones.

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APPENDIX A

CONSTRUCTION STUDY PROJECTS

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CANDIDATE PROJECTS

A. PAVEMENT CRACKING & SEATING (3 Projects)

```
Cand  Route/Location       Yr. TCP Dur  Lngth Cost ADT   Alt Fld  Study
 No    Description                 (Mo) (Mi.) ($M)       TCP Stdy  Pot
----  --------------       ---- --- ---- ----- ---- ---- --- ---  ---

West Virginia (2)

1. I-70 Elm Grove-Dal Pke  86A  LC   6   5.5  2.9 24500  N   ?
    S335-70-4.82, IR-0701(066)005 (0.2 Mi. Pavt Restor)(Beg Spr 87)

2. I-64 Ona Mall           86A  LC   4   1.2  1.2 20500  N   ?
    S306-64-18.49, IR-0641(152)018 (Beg Spr 87)

Kentucky (1)

6. Bluegrass Pkwy          87P  LC   ?   ?    ?   4500  N   N

                                                         2/20/87
```

CANDIDATE PROJECTS

B. CONCRETE PAVEMENT OVERLAY (11 Projects)

```
Cand  Route/Location       Yr. TCP Dur  Lngth Cost ADT   Alt Fld  Study
 No    Description                 (Mo) (Mi.) ($M)       TCP Stdy  Pot
----  --------------       ---- --- ---- ----- ---- ---- --- ---  ----

Michigan (5)

1. I-94  SR51-SR40         86C TLT  7    5.0  6.7 18700  N   N
2. I-94  11Mi Rd - Old US27  86C  TLT    6       5.8    $7.8M  29000
   13082-24914  Pavement Recycled)
6. I-96  (Near Clarksville)  87P  TLT   15       8.2     8.2M  12800

   80024-24754
7. I-94 Helmer Rd-Beadle 87P TLT  8    4.3  3.0 26500  N   ?
   13081-24112  (Pavt to be pulverized prior to overlay)
8. I-94 Van Buren-PawPaw 87P TLT  8    5.8  7.0 18500  N   N     Yes


Oregon (4)

1. I-5 Albany,Linn Co    84C TLT 28    7.0 12.6 24200  N   N     Yes
   IR-5-4(95)228  ( 3Intgs kept open,ex pavt removed)
2. I-5NB Goshen-Saginaw  84C TLT 20   13.2  6.7 23700  N   N
   IR-5-3(132)174 (NB Only,asph overlay remvd, 3intgs kept open)
5. I-5SB Elkhead-RiceHil 84C  *  23    7.1  2.1 13100  N   N
   IR-5-3(131)147 (* Partial detour + TLTWO w/conc bar, recycled)
6. I-84 Meacham-LaGrange 86C Both 6     ?   3.8  5550  N   N     Yes

Utah (2)

4. I-15 N. Beaver-Wilcat 85A? TLT 18   8.8 11.2  5750  N   N     Yes
   IR-15-3(22)112  (Conc Bar)
5. I-80 Lake Pt Jct      85C  TLT 20?  4.9 10.9 12433  N   N     Yes
   IR-80 2(25)97 (Vert align corr, partial TLTWO on US40 )    2/20/87
```

CANDIDATE PROJECTS

C. CONCRETE PAVEMENT RESTORATION (6 Projects)

Cand No	Route/Location Description	Yr.	TCP	Dur (Mo)	Lngth (Mi.)	Cost ($M)	ADT	Alt TCP	Fld Stdy	Study Pot
Kentucky (2)										
5.	I-75 Whitly-Laurel Co (Spot pavt repl & joint sealing)	86A	LC	3	50.7	3.9	20000	N	N	
8.	WesternKyPkwy,Ohio Co	87P	LC	?	?	?	4000	N	N	Yes
Louisiana (1)										
12.	I-10 Acadia to I-49 450-05-28 (Funding Delay)	87P	LC	12	10.0	9.2	18000	N	N	Yes
North Carolina (2)										
7.	I-40 Iredell Co 8.1820401,IR-40-2(70)148 (Extens TCP Rev dur Constr, Iowa Weave)	83C	LC	20	5.2	3.3	35000	N	N	Yes
8.	I-95 Johnston Co 8.1310101,IR-95-2(73)97 (Bridge rehab in one-half sections)	84C	LC	26	10.0	3.3	20000	Y	N	Yes
Oregon (1)										
4.	I-5 Grant's Pass So. IR-5-1(111)042 (Some conc bar in LC, TLTWO w/bar)	86A	Both	17	15.5	4.2	18300	N	N	Yes

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CANDIDATE PROJECTS

D. ASPHALT CONCRETE OVERLAY (35 Projects)

Cand	Route?Location Description	Yr.	TCP	Dur (Mo)	Lngth (MI.)	Cost ($M)	ADT	Alt TCP	Fld Stdy	Study Pot
Arizona (5)										
9&10	Munds Pk-Airport IR-17-2(100)&(102) S(+Hand Rail Repl-3 Brs, Redeck 1 Br)	3/87P	?	?	13,8	4.9	9600	N	N	
11.	I-10 Brenda-N Wtr IR-10-1(66) MP 29.6 (Milling)	4/87P	?	?	10.0	1.1	8000	N	N	Yes
12.	I-40EB Winona-TwAr IR-40-4(118) MP212 (Eastbooun Only)	4/87P	?	?	5.8	2.0	9500	N	N	
13.	I-17 BadgSprg-Cordes IR-17-1(168) MP256	7/87P	?	?	6.7	3.8	14000	N	N	
14.	I-17 Camp Verde IR-17-2(98) MP286	8/87P	?	?	5.4	1.8	13000	N	N	
15.	I-295(SR9A)Jacksnvle 72001-3452 (Compl schd 5/87)	86A	LC	185	4.5	1.9	20000+	N	Y?	Yes
16.	SR9A Jacksonville 72001-3453	86A	LC	255	7.3	2.2	26000+	N	Y?	Yes
Florida (15) (Duration in days)										
1.	SR91, Tpk Ind R Co 97880-9315	86A	LC	220	9.0	2.3	7500	N	N	
6.	SR55 30010-3512	86C	LC	250	8.6	1.5	6070	N	N	
7.	SR121 NW34th St 26250-3518 & 3519 (2 lane?)	86C	LC	100	0.8	0.4	20620	N	N	
8.	US 1 (SR5) Stuart 89010-3540	86C	LC	115	2.3	0.6	29300	N	N	
9.	SR 15 Jacksonville 72030-3528	86C	LC	205	2.1	1.5	39100	N	N	
10.	I-10(SR8) SWMacCleny 27090-3424	86C	LC	209	11.1	2.7	13840	N	N	
11.	I-75(SR93)NWLakeCity 29180-3442 (ADT also 14250)	86C	LC	150	12.4	1.6	27620	N	N	
12.	I-75(SR93)SanteFeRNo 29180-3443	86C	LC	200	13.2	2.1	28190	N	?	
13.	SR55 Chfdn-Fng Sprgs 34010-3526	86A	LC	170	8.8	1.5	12100	N	N	
14.	I-10(SR8) NE LiveOak 37120-3418	86C	LC	255	10.3	2.6	11400	N	N	
19.	US27 SE Fla 93160-3530	86C	LC	105	6.7	0.7	10000?	N	N	
20.	US1 (SR5) So Stuart 89010-3544	85C	LC	260	3.8	1.5	29300	N	N	
21.	Fla Tpke Near FtLaud 97860-3319	86A	LC	500	?	5.2	76000	N	?	

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D. ASPHALT CONCRETE OVERLAY (Continued)

Cand No	Route/Location Description	Yr.	TCP	Dur (Mo)	Lngth (Mi.)	Cost ($M)	ADT	Alt TCP	Fld Stdy	Study Pot
Kentucky (1)										
4.	SR114 Clar/Powell Cos	86A	LC	175	12.3	7.0	7000	N	N	Yes
	(Mountain Pkwy)									
Louisiana (4)										
2.	I-10 New Orleans	87P	LC	6	4.6	1.7	98070	N	N	No
	450-15-78 (6 Lanes, Night work?)									
3.	I-10 SR22-Blind River	86C	LC	7	9.0	4.0	24070	N	N	Yes
	450-11-24 (Conc Pavt repl prior to overlay)									
4.	I-12 Hammond East	86C	LC	3?	13.0	12.9	21610	N	N	
	454-03-21									
11.	I-10 Ibervle-Westvr	87P	LC	10	8.0	4.6	27000	N	?	Yes
	450-08--22 (Funding Delay?)									
North Carolina (6)										
11.	I-95 Cumberland Co	84C	LC	21	13.0	1.9	24000	Y	N	
	8.1440301/Ir-95-2(74)56 (Drumclos, rehab br halfs, 2"pavt milled and recycled)									
12.	I-95 Johnston/HarneCo	84C	TLT	29	10.6	1.2	20000	Y	N	Yes
	8.1450201, IR-95-2(75s)69 (Similar to #11)									
*14.	US70 Durham Co	86A	LC	10	2.5	0.8	26600	N	?	
	8.1350501/FR-66-1(15) (Incl constr 2' Pavd Shldr)									
*15.	US64 Nash Co	86C	LC	9	15.0	2.4	9000	N	N	
	8.1320101/FR -36-1(24) (Incl milling, shldr drains)									
*16.	US64/264 Wake/Frnk Co	86C	LC	9	16.4	2.9	9600	N	N	
	8.1400701/901, FR-38/36 (Incl Milling, Shldr Drains)									
*17.	I-85 Guilford Co	85A	LC	23	11.2	2.4	46300	N	?	Yes
	8.1491001/IR-85-3(110)126									
	*Added 2/27/86									
Utah (2)										
1.	I-70 W Greenriv-Floy	87P	LC	6	16.0	5.5	3818	N	N	
	I-IR-70-3(25)161 (3 1/2 asph + sealcoat)									
2.	I-15 Baker Ca-Meadow	87P	LC	6	15.3	4.0	4482	N	N	Yes
Oregon (1)										
8.	I-84 Eagle Cr-MitchPt	87P	LC	4	16.9	0.1	?	N	Y?	Yes
	IR-84-2(21)042									
Michigan (2)										
9.	I-94EB Chelsea	86C	LC	?	6.5	2.3	26600	N	N	
	81104-24255 (Eastbound Only)									
10.	I-96 Coll Rd-Meridian	87P	LC	?	6.0	1.8	24500	N	N	Yes

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E. BRIDGE DECK OVERLAY (9 Projects)

Cand No	Route/Location Description	Yr.	TCP	Dur (Mo)	Lngth (Mi.)	Cost ($M)	ADT	Alt TCP	Fld Stdy	Study Pot
Kentucky (1)										
	I-75 Whitley-Laurel Cos	87P	LC	?	0.2	0.4	20000	N	?	Yes
Michigan (2)										
4.	US131 I-94 over US131	86A	LC?	?	0.1	0.2	23600	N	N	Yes
	39014-21875 (Ramps Closed)									
5.	I-196 3 bridges	86A	LC	?	0.3	0.5	11400	N	N	Yes
	11111-24322, 80012-24322 (Conc Bar Closure)									
West Virginia (6)										
3.	I-64 Kenova Br #2087	86A	LC	6	0.7	0.2	13000	N	N	Yes
	6350-64-1.25/IR-0641(144)001 (Late Overlay, Compl 6/87)									
4.	I-81 Martinbur Bridge	86A	LC	6	0.7	0.2	24000	N	N	
	8302-81-13.51/IR-0811(044)013 (Latex Overlay, Compl 4/87)									
7.	I-64WB Gimlet Hol#2227	86A	LC	6	1.0	0.2	15000	N	N	
	8306-64-5.97/IR-0811(158)006 (Latex Ovrlay Westbound Only)									
8.	I-79 Amma #2682	86A	LC	18	0.5	1.5	5600	N	N	Yes
	8344-79-25.79/ IR-0791(056)025 (4 bridges)									
12.	I-77 East RivMtn Tun	86A	LC	6	1.2	0.7	10000	N	N	
	8328-77-2.95/IR-77-1(23)3 (Latex Overlay)									
13.	I-79 Weston Intge	86A	LC	6	1.5	0.7	8400	N	N	

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CANDIDATE PROJECTS

F. BRIDGE DECK REPLACENMENT AND WIDENING (14 Projects)

Cand No	Route/Location Description	Yr.	TCP	Dur (Mo)	Lngth (MI.)	Cost ($)	ADT	Alt TCP	Fld Stdy	Study Pot
Arizona (4)										
2.	I-40 Tw Wash-Apach Co	86A	LC?	11	4.2	2.3	9800	Y	N	Yes
	IR-40-5(67) MP303									
3.	I-15 Virgin River Br	86C	TLT	11	0.8	2.8	6700	Y	N	
	IR-15-(35)&1(34) MP9									
6.	I-10 Ocotillo Rd	86A	TLT	5	0.2	1.5	12000	Y	N	Yes
	IR-10-6(103) MP304 (+Guard Rail, Incentive clause)									
8.	I-10EB Benson SPRR	2/87P	?	?	0.2	0.1	12000	N	N	
Oregon (1)										
3.	I-84 Warr-Lyento StPk	85C	LC	12	20+	0.4	12300	N	N	Yes
	IR-84-2(16)36 (Bridges Widen, Culvert Repair)									
Kentucky (1)										
3.	SR 80 Floyd County	87A	TLT	?	1.0	?	10000	N	N	No
	(Temp TLTWO, Now Closed)									
Louisiana (1)										
1.	US 190 Baton Rouge	86A	TLT	13	1.0	15.0	15790	N	N	Yes
North Carolina (3)										
6.	I-240 Ashville	85A	4LT	22	0.3	5.1	70000	Y	N	No
	8.140401/BHI-240-1(19)4 (2-4 Lane Bridges, Incentive clause)									
9.	US 1 No of Raleigh	85C	TLT	?	0.5	0.9	15000	Y	N	Yes
	8.1401001/BRF-43-3S(12) (Asphalt divider)									
10.	I-240 Ashville	87P	TLT	24	1.2	3.5	35000	Y	?	Yes
	8.1840402/IR-240-1(20)4 (Conc Restor, Bridge Rehab)									
West Virginia (4)										
5.	I-64 Winfield-St Alb.	87P	TLT	18	0.6	2.8	46000	Y	?	Yes
	S340-64-41.51/IR-0641(137)41 (Deck Repl/Widen)									
6.	I-77 Spicewood Creek	86A	TLT	6	0.6	1.7	17000	N	N	Yes
	S318-77-119.26/IR-0773(159)119 (New Deck, Pictures)									
9.	I-70 Wheeling,Fulton	86A	TLT	20	0.5	2.0	39000	N	?	Yes
	S335-70-1.92/IR-70-1(37)2 (Intge within CZ, Lane Drop)									
10.	I-64 Hurricane	87P	TLT	18	1.0	3.1	36000	Y	?	
	S340-64-33.13/IR-0641(135)33 2 Bridges (Pictures)									
11.	I-470 So Wheeling	86A	LC	8	0.7	1.2	18000	N	?	
	X335-470-0.00,C-4/I-470-1(17)0,C-2 (Cable Repl, Conc Bar)									

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CANDIDATE PROJECTS

G. RECONSTRUCTION (24 Projects)

Cand No	Route/Location Description	Yr.	TCP	Dur (Mo)	Lngth (Mi.)	Cost ($M)	ADT	Alt TCP	Fld Stdy	Study Pot
Arizona (3)										
1.	I-40EB RiordonOP-US89A	86C	TLT	8	4.1	6.4	9400	N	N	
	IR-40-3(62) MP191 (Eastbound Only)									
4.	I-10 Gila R Br Apprs	86C	LC	5	0.1	1.1	19000	N	N	
	ER-10-3(212) MP304 (Wide Veh Detour)									
5.	I-8	86C	?	7	5.1	2.2	5500	N	N	Yes
	IR-8-2(86), MP 160.8 (+ Overlay, GR & Culvert)									
Florida (5)										
2.	SR80 Palm Beach Co	85C	LC	635	5.6	10.0	5800	N	N	Yes
	93120-3524									
3.	SR710	85C	LC	400	5.5	4.4	8010	N	N	
	93310-3512									
4.	US29(SR95) LanogCr-C4A	86A	LC	340	2.1	4.3	6000	N	N	
	418060-3519 (Bid 8/87, Overlay, Guard Rail, Culvert)									
5.	SR95 CR4A-CR4West	86A	TLT	470	3.0	4.9	4900	N	N	
	48060-3515 (Widen 2 to 4 lanes)									
17.	SR710(BeeLine)	84C	LC	346	3.4	2.6	6260	N	N	
	93310-3511 (So of Palm Beach Gardens) (Two Lanes Added)									
Kentucky (1)										
2.	US127 Boyle Co	87P	TLT	?	?	?	12000	N	N	Yes
Louisiana (7)										
5.	I-12 Us61-O'Neal	86A	2L	13	5.0	15.2	48420	N	N	No
	454-01-40 (Widen 4 to 6 lanes, not eligible)									
6.	I-59 Pearl R Br-Miss L	86A	TLT	23	5.0	10.6	22190	N	N	Yes
	453-01-28									
7.	I-20 McIntyre-DixieInn	86A	TLT	8	2.6	4.9	27590	N	?	Yes
	451-03-37									
8.	I-20 Ruston-Choudrant	86A	TLT	14	7.0	11.9	23870	N	N	
	451-05-59									
9.	I-20 Rayville-Holly Rg	86A	TLT	12	6.7	10.5	16540	N	N	Yes
	451-07-30 (Asphalt Divider)									
10.	I-20 SR17-SR577	87P	TLT	13	6.0	8.1	13700	N	N	
	451-07-29, -08-29									
13.	I-10 Sulphur-Westlake	87P	TLT	20	5.0	10.8	32000	N	?	Yes
	450-91-42 (Funding Delay?)									

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CANDIDATE PROJECTS

G. RECONSTRUCTION (Continued)

Cand No	Route/Location Description	Yr.	TCP	Dur (Mo)	Lngth (Mi.)	Cost ($M)	ADT	Alt TCP	Fld Stdy	Study Pot
North Carolina (5)										
1.	I-40 West Ashville	84C	LC	30	10.8	7.6	15000	N	N	
	8.19440201/IR-40-1(93)4 (Bridge Rehab,GR Upgr, Perm Conc Bar)									
2.	I-40 West Ashville	85A	TLT	24	14.2	8.7	25000	Y	?	Yes
	8.1940205/IR-40-1(99)23 (8 Bridges + Same as #1)									
#3.	I-85 Charlotte (11/88)	87P	Both	24	6.4	4.1	30000	Y	?	
	8.1671501/IR-85-2(31)42 (Conc Restor, New Conc Bar,Temp Use)									
#4.	I-40 Ashville-Morgan	87P	TLT	24	7.0	7+	17000	Y*	N	Yes
	8.1870201/IR-40-2(72)71 (Sim to #3 w/Incentive clause)									
#5.	I-77 Charlotte(11/88)	87P	QC	24	9.2	6.0	32000	Y	?	Yes
	8.1671701/I-77-1(103)14 (Sim #3, 5"overlay, Quick change bar)									
Oregon (1)										
7.	I-5 McKenzie-WillemteR	86A	TLT	24	4,4	18,5	31500	N	?	
	IR-5-4(102)193 (Widen to 6 lanes betw Intgs, partial 4LTWO)									
Utah (2)										
2.	I-70 Salina Canyon	86A	?	4	0.5	?	2350	N	N	No
	ER-70-2(29)59 (Slide Correction, not comparable)									
6.	I-84 W.Trem-Blu Cr Sum	84C	TLT	24	10.9	20.8	4372	N	N	Yes
	I-84-5(7)29 (Added 2 new lanes)									

#Transferred from D. Conc Overlay Projects, 2/27/87
*Furnished

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CANDIDATE PROJECTS

H. NEW AND INTERCHANGE CONSTRUCTION (5 Projects)

Cand No	Route/Location Description	Yr.	TCP	Dur (Mo)	Lngth (Mi.)	Cost ($)	ADT	Alt TCP	Fld Stdy	Study Pot
Arizona (1)										
7.	I-10 Tucson,Kino Intg	86A	LC	8	1.0	7.1	33000	N	Comp	Yes
	IR-10-5(60),(61) (Br Ovpass + New Ramps)									
Florida (1)										
18.	US441(SR80)NE Belgrd	84C	LC	620	13.1	7.1	5340	N	N	Yes
	93110-3510									
Kentucky (1)										
1.	I-75 Scott County	87P	TLT	?	1.0	?	25000	Y	?	Yes
	(Toyota Plant Intge, partial TLTWO)									
Michigan (1)										
3.	US127 Lansing	86A	TLT	?	2.0	15.5	15500	N	N	Yes
	19042-24681 (Contr. Negot. resulted in TLTWO w/Conc Bar)									
North Carolina (1)										
13.	I-40 Durham	85A	LC	24	2.7	5.8	30000	Y	?	Yes
	8.1350401/IR-40-4(74)282									

2/20/87

Study Project - California # A1
Concrete Pavement Recycling/Overlay

Method of Traffic Control: Single Lane Closure, Tubes

Route: Interstate 80 Fed. Proj. IR-BHI-080-4(135)166
State Proj.

Location: Placer and Nevada Counties, Donner Pass

Project Length: 6.30 miles Average Daily Traffic - 21,600

Construction Costs: Total - $ 13,295,635 (Incomplete Final Costs)
Traffic Control - $ 1,142,300 (9 %)
Alternate - $ 1,224,569
$ 1,387,490 (4LTWO)

Construction Period: Started - 2/24/88 (Bid Opening)
Completed - Est. 8/89 (350 working days)

Description: Concrete Pavement Overlay. PCC (8") unbonded overlay on AC (1") over existing PCC (8") with cement treated base (4"), with transverse skewed joints, bridge deck repairs.

Bridges: 1. Nine structures. Remove Exstg. AC Surf., Scarify Deck (1 1/4"), New 7" RCP Deck, GM Par. Wall, Reinf. Pier (Bent)

Other Significant Comments:
1. Project added late, no accident data or file data collected.
2. Existing full shoulder on median side (10') permitted traffic maintenance in 2 lanes directional, on each side I-80.
3. Traffic maintained in two lanes in each direction, using full shoulder (10') left and right and adjacent lane.
4. Existing lanes coated with AC and two 11' lanes maintained during construction.
5. Single lane closure permitted during concrete pours.
6. Bridge Deck Work performed in 3 Stages

Study Project - Michigan #A2
Concrete Pavement Recycling/Overlay

Method of Traffic Control: TLWTO, Asphalt Divider, Tubes

Route: Interstate 94 Fed. Proj. ACIR-94-3(195)104
State Proj. 24914

Location: Calhoun County, East of 11 Mile Road to East Old US 27

Project Length: 5.80 miles Average Daily Traffic - 29,000

Construction Costs: Total - $ 7,968,964
Traffic Control - $ 892,065 (11%)
Alternate - $ 1,252,960

Construction Period: Started - 5/9/86
Completed - 11/14/86

Description: Concrete Pavement & Shoulder Reconstruction, Recycling, Permanent Signing. Remove & Recycle 9" RCP & remove 3" Subbase, & add RCP (10") on Sand Base (4"). Includes two Interchanges.

Bridges: 1. None

Other Significant Comments:
1. Legislative Speed Limit 45 mph
2. Completion incentive awarded $ 66,000 (22 days @ $ 3,000/day
3. Construction time will also increase an indeterminable amount of time.

Study Project - Oregon # A1
Concrete Pavement Recycling/Overlay

Method of Traffic Control: TLTWO, Concrete Barrier

Route: Interstate 5 **Fed. Proj.** IR-5-4(95)228
State Proj.

Location: Linn County, New Albany to Corvallis

Project Length: 7.04 miles **Average Daily Traffic** - 24,200

Construction Costs: Total - $ 12,012,163
Traffic Control - $ 829,722 (7 %)
Alternate - N/A SLC not economically feasible.#

Construction Period: Started - 8/14/84
Completed - 10/10/86

Description: Concrete Pavement Inlaid, Continuously RCP (11") over recycled existing (8") PCC, grading, guard rail. Three interchanges. Median width 64'.

Bridges: 1. Total of 12 structures, 4 individual and 4 pairs of structures, varying in length from 72' to 243'. Latex modified overlays.

Other Significant Comments:
1. Temporary concrete barrier State policy for TLTWO for liability reasons.
2. Three interchanges kept open during construction with full access.
3. Maximum length of TLTWO of 3 miles.
4. Poor subbase material required extensive additional work.
5. Profile raised 2 inches.
6. Met w/Resident Engineer. Commented that the project could have been constructed in two stages, instead of three, and exceed 15,000 feet maximum TLTWO length. No safety problems encountered.
7. Some delays holiday/football weekends
8. Corrections made to geom. temp. entr. ramps.

#9. Reviewed by ACPA. Est. +16% Cost+time

10. Some accidents at median crossovers because of tight geometrics. Geometrics improved.

Study Project - Oregon # A2
Concrete Pavement Recycling/Overlay

Method of Traffic Control: TLTWO, Temporary Concrete Barrier

Route: Interstate 5 **Fed. Proj.** IR-5-3(132)174
Northbound Only **State Proj.**

Location: Lane County, Goshen to Cottage Grove

Project Length: 13.18 miles **Average Daily Traffic** - 22,550

Construction Costs: Total - $ 9,940,549
Traffic Control - $ 366,308 (3.5 %)
Alternate - N/A SLC not economically feasible.

Construction Period: Started - 3/11/85
Completed - 10/16/87

Description: Concrete Pavment Inlaid, Continuously RCP (10") with existing 8" PCC pavement recycled for base, grading, bridge deck latex overlays (11),landscaping, roadway lighting. 3 interchanges. Northbound only. Median width 48'.

Bridges: 1. 11 structures, 52' to 434' in length, latex overlays & some joint repair.

Other Significant Comments:
1. Work in Northbound lanes only.
2. Maximum closure length, 3 miles.
3. 3 interchanges kept open.
4. Temporary concrete barrier State policy for TLTWO for liability reasons.
5. Profile grade raised 2".

Study Project - Utah # A4
Concrete Pavement Recycling/Overlay

Method of Traffic Control: TLTWO, Temporary Concrete Barrier

Route: Interstate 15 **Fed. Proj.** IR-15-3(22)112
State Proj.

Location: Beaver County, North Beaver to Wildcat

Project Length: 8.769 miles **Average Daily Traffic** - 5,218 (Avg.)

Construction Costs: Total - $ 11,640,004
Traffic Control - $ 1,234,783 (10.5 %)
Alternate Constr. + $1,097,500 (add'l constr. cost)
Alternate TCP - $ 109,428

Construction Period: Started - 7/10/85
Completed - 11/15/86

Description: Concrete Pavement Overlay. 10.5" PCC, over existing " Safety Upgrading, Grading (flatten slopes), guardrail removal, bridge deck repair. One interchange. Median width 52' to 140'.

Bridges: 1. One pair structures, 108.38' in length. (Width 38.0' Deck, parapet rehabilitation.

Other Significant Comments:
1. TLTWO in one operation (9 miles).
2. Interchange closed during construction.
3. ACPA input on Alternate Analysis. (+ 9.4 % Construction Cost)
4. Est. Avg. $5,000/day motorist claims for Single Lane Closure. (Alt. TCP)
5. Significant TCP cost in Mobilization.

Study Project - Utah # A5
Concrete Pavement Recycling/Overlay

Method of Traffic Control: TLTWO, Drums & Temporary Concrete Barrier & Single Lane Closure, Drums

Route: Interstate 80 **Fed. Proj.** IR-80-2(25)97
State Proj.

Location: Tooele and Salt Lake Counties, South of Great Salt Lake, West of Lake Point to Black Rock

Project Length: 4.871 miles **Average Daily Traffic** - 12,860 (Avg.)

Construction Costs: Total - $ 11,570,513
Traffic Control - $ 1,195,715 (10 %)
Alternate - N/A No SLC Alternate Feasible

Construction Period: Started - 9/3/85
Completed - 12/9/86

Description: Project to raise profile I-80 (6'-8') to minimize high water problem on Great Salt Lake. Concrete Pavement Overlay. PCC (11") over existing AC (10"), structure rehabilitation, grading, lighting, temporary traffic signal.

Bridges: 1. None on I-80.

Other Significant Comments:
1. Detour both directions over US 40 w/TLTWO during concrete overlay of 4500'+ of I-80.
Temp. Concrete Barrier, by C.O. US 40
2. TLTWO w/drums on I-80 during overlay
3. Single Lane Closure during asphalt base course construction raising profile.
4. Significant TCP cost in Mobilization by Specs.
5. Additional cost for advance flaggers for worker equipment protection.
6. Extensive AC leveling on WB I-80 to remove existing ruts & low spots.
7. Met w/Project Engineer.

Study Project - Louisiana #B14
Concrete Pavement Restoration

Method of Traffic Control: Single Lane Closure

Route: Interstate 20 Fed. Proj. None
State Proj. 451-07-36

Location: Richland Parish, Start to Rayville

Project Length: 5.65 miles **Average Daily Traffic** - 23,470

Construction Costs: Total - $ 699,782
Traffic Control - $ 15,000 (2 %)
Alternate - $ 585,988*

Construction Period: Started - 4/20/87
Completed - 7/2/87

Description: Concrete pavement restoration, full depth patching of 10" PCC, joint repair & undersealing of joints, including cold planing 1 1/2" AC continuous for length of project on shoulders (recycled.) Includes one interchange.

Bridges: 1. None

Other Significant Comments:

1. Contract by purchase order for expediting project.
2. Speed limit 45 by statute during construction.
3. Right lane construction 15' width with 7' paved shoulder.
*4. Predominant work upgrading shoulders. Minimal pavement replacement. TLTWO not cost effective.

Study Project - North Carolina # B7
Concrete Pavement Restoration

Method of Traffic Control: Single Lane Closure, Iowa Weave by C.O.

Route: Interstate 40 Fed. Proj. IR-40-2(70)148
State Proj. 8.1820401
TIP # I-809

Location: Iredell County, Statesville, City Line east to US 64

Project Length: 5.819 miles **Average Daily Traffic** - 35,000

Construction Costs: Total - $ 4,056,619
Traffic Control - $ 235,927 (6 %)
Alternate - $ 706,029

Construction Period: Started - 2/6/84
Completed - 9/5/85

Description: Concrete Pavement Restoration, Bridge deck repairs, guard rail, grading, shoulder widening, pavement markings, signing. 3 interchanges.

Bridges: 1. 4 pair of bridges plus one pair on I-77 over I-40, length varies from 145' to 265'. Deck rehabilitation & tubular railing.

Other Significant Comments:

1. 45 mph work zone speed limit added after 3 worker accidents.
2. Iowa Weave used during construction.
3. Ramps closed as necessary for bridge deck repairs.
4. 2 mile limit on lane closures.
5. Extensive TCP modifications during construction.
6. Estimated pavement quantities increased 100 % during construction.
7. Significant increases in temporary pavement markings & signs during construction.

Study Project - North Carolina # B8
Concrete Pavement Restoration

Method of Traffic Control: Single Lane Closure, Drums, Iowa Weave added by C.O.

Route: Interstate 95 **Fed. Proj.** IR-95-2(73)97
State Proj. 8.1310101
TIP # I-817

Location: Johnston County, US 70A at Selma to Kenly

Project Length: 10.048 miles **Average Daily Traffic** - 20,000

Construction Costs: Total - $ 4,901,963*
Traffic Control - $ 216,345 (4 %)
Alternate - $ 1,166,218

Construction Period: Started - 8/20/84
Completed - 4/27/86

Description: Concrete pavement restoration, Bridge deck rehabilitation & railing retrofit. 5 Interchanges & 1 rest area.

Bridges: 1. 3 pairs of structures, 210' to 404.25' in length. Bridge deck repairs and railing retrofit.

Other Significant Comments:
1. Detour for overwidth vehicles.
2. Lane closures, max. length 2 miles, minimum one mile between closures.
3. Initial speed zone 45 mph modified to apply to work zones only. Flip signs used, 55-45.
4. Problems with 28' bridge deck widths.
5. Iowa Weave added by C.O. for NB traffic, south end project.
6. Extensive increases in temporary pavement markings & concrete barrier.
*7. Project time extensions needed & high cost overruns.
8. Work zone problems prompted intiation of TLTWO in North Carolina.
9. Traffic backups on holiday weekends
10. Special Provisions - $2,500/day liquidated damages for I-95 Bridge over Seaboard Coast RR.

Study Project - Ohio # B1
Concrete Pavement Restoration

Method of Traffic Control: Single Lane Closure, Drums

Route: Interstate 75 **Fed. Proj.** IR-75-6(73)179
State Proj. 273 (87), WOO-75-14.91

Location: Wood County, East of Bowling Green, Ohio 64 to Ohio 582

Project Length: 5.016 miles **Average Daily Traffic** - 25,358

Construction Costs: Total - $ 3,615,648
Traffic Control - $ 299,935 (8 %)
Alternate - $ 562,795

Construction Period: Started - 7/11/87
Completed - 12/11/87

Description: Concrete Pavement Restoration (8"PCC), Concrete pavement patching, 10' concrete shoulders (3" PCC), 4' asphalt concrete shoulders (1 1/4"). No interchanges. Median width 84'

Bridges: 1. Two pairs of structures, 66.75' and 203.65' in length. Deck patching and approach slabs.

Other Significant Comments:
1. Field delay studies conducted.
2. Extensive holiday & weekend delays reported.
3. Maximum lane closure 2.5 miles.
4. Review and comments by ACPA.
5. Delays during construction work due concrete paving operation/other work.

Study Project - Oregon # B4
Concrete Pavement Restoration

Method of Traffic Control: Single Lane Closure, TCB for restoration work; TLTWO, TCB for bridge work only.

Route: Interstate 5 **Fed. Proj.** IR-5-1(111)043
State Proj.

Location: Josephine & Jackson Counties, N. Grant's Pass to Rock Point

Project Length: 15.52 miles **Average Daily Traffic** - 20,550

Construction Costs: Total - $ 9,186,788
Traffic Control - $ 562,754 (6 %)
Alternate - $ 947,598 (TLTWO entire project, TCB)

Construction Period: Started - 3/25/86
Completed - 7/21/87

Description: Concrete Pavement Restoration. Reinforced PCC (12") Patching & AC Shoulders (2"), drainage, bridges (15) Median width 8.4' to 64'.

Bridges: 1. 15 structures, 144' to 809' in length. Latex overlays and some joint repairs.

Other Significant Comments:
1. SLC w/TCB used for pavement restoration work.
2. TLTWO w/TCB used for bridge work.
3. During bridge work, detours provided w/interchanges closed to access.
4. Temporary concrete barrier State policy for TLTWO for liability reasons.
5. Maximum 3 miles TLTWO.
6. Extensive pavement replacement (quantity doubled) due to length of time between preliminary field inspection & actual construction - several years
7. If two concurrent work areas, two miles unrestricted flow required by plans between end of one section and begin signing for 2nd

Study Project - Arizona #C5
Asphalt Concrete Overlay

Method of Traffic Control: Single Lane Closure

Route: Interstate 8 **Fed. Proj.** IR-8-2(86)

Location: Pinal County, Stanfield TI to Midway Road

Project Length: 5.13 miles **Average Daily Traffic** - 5,900

Construction Costs: Total - $ 2,222,615
Traffic Control - $ 247,029 (11 %)
Alternate - $ 311,200

Construction Period: Started - 5/20/86
Completed - 11/22/86

Description: Milling (2 1/2") & Recycled Asphalt Concrete Pavement (4") and Safety Upgrading

Bridges: 1. Over Sante Rosa Wash, Length 620', Width 30'. Replace curb parapets w/barrier shape.

Other Significant Comments: 1. One worker accident, fatal when worker fell asleep driving truck.

Study Project - Arizona #C11
Asphalt Concrete Overlay

Method of Traffic Control: Single Lane Closure

Route: Interstate 10 **Fed. Proj.** IR-10-1(66)

Location: La Paz County, Brenda to New Water

Project Length: 12.10 miles **Average Daily Traffic** - 8,000

Construction Costs: Total - $ 3,011,793
Traffic Control - $ 75,711 (2.5 %)
Alternate - $ 583,600

Construction Period: Started - 11/12/87
Completed - 7/26/88

Description: Asphalt Concrete Overlay (3" + 1.5"), Milling (3") to remove & recycle asphalt concrete. Determined that heavy truck traffic warranted thicker surface course and surface course non-performed for later work by separate contractor.

Bridges: 1. Two bridges, 164' & 111' within project, but no work on structures determined in bid analysis.

Other Significant Comments: 1. All contractors furnished $90,000 required bid for Traffic Control.

2. Final cost reduced by non-performance of surface course because of need for additional structural thickness and separate contract. (Cost too high for adding by Change Order.)

Study Project - Florida #C15
Asphalt Concrete Overlay

Method of Traffic Control: Single Lane Closure

Route: Interstate 295 **Fed. Proj.** ACIR-295-5(147)16
State Proj. 72001-3452

Location: Duval County, City of Jacksonville

Project Length: 4.771 miles **Average Daily Traffic** - 20,000

Construction Costs: Total - $ 1,865,670
Traffic Control - $ 137,851 (7 %)
Alternate - $ 580,158

Construction Period: Started - 11/5/86
Completed - 10/27/87

Description: Asphalt Concrete Overlay (3" Est. AC structural course 300#/SY + 5/8" friction course) with milling (3" typical) on I-295 including ramps to and from three interchanges including Interstate 10.

Bridges: 1. None

Other Significant Comments: 1. None

Study Project - Florida #C16
Asphalt Concrete Overlay

Method of Traffic Control: Single Lane Closure

Route: Interstate 295 **Fed. Proj.** ACIR-295-5(148)9
State Proj. 72001-3453

Location: Duval County, City of Jacksonville

Project Length: 7.522 miles **Average Daily Traffic** - 26,000

Construction Costs: Total - $ 2,466,210
Traffic Control - $ 160,599 (6.5 %)
Alternate - $ 747,453

Construction Period: Started - 1/25/87
Completed - 3/25/88

Description: Asphalt Concrete Overlay (3" Est. AC structural course 300#/SY + 5/8" friction course) with milling (3" typical) on Interstate 295 including ramps to and from three interchanges. Some guard rail replacement.

Bridges: 1. None

Other Significant Comments: 1. $6,300 assessed for liquidated damages.

Study Project - Kentucky #C4
Asphalt Concrete Overlay, Breaking and Seating

Method of Traffic Control: Single Lane Closure

Route: Kentucky Route 114 **Fed. Proj.**
State Proj. F 6-1(7)

Location: Clark/Powell County, Mountain Parkway

Project Length: 12.495 miles **Average Daily Traffic** - 7,590

Construction Costs: Total - $ 7,602,570
Traffic Control - $ 199,094 (2.5 %)
Alternate - $ 318,952

Construction Period: Started - 9/25/85
Completed - 12/17/86

Description: Asphalt Concrete Overlay (3" base, 1 1/2" binder, 1" surface course), breaking and seating, remove median curb & reshape median, guard rail, crash cushions Pavement

Bridges: 1. No work

Other Significant Comments: 1. Break and Seat Existing Pavement

Study Project - Louisiana #C3
Asphalt Concrete Overlay

Method of Traffic Control: Single Lane Closure, Drums

Route: Interstate 10 **Fed. Proj.** IR-10-4(095)186, IR-10-4(096)190
State Proj. 450-11-24, 450-12-13

Location: Ascension & St. James Parishes, La. Rt. 22 to Blind River

Project Length: 8.957 miles **Average Daily Traffic** - 24,070

Construction Costs: Total - $ 3,588,713
Traffic Control - $ 52,500 (1.5%)
Alternate - $ 831,385

Construction Period: Started - 3/17/86
Completed - 6/30/87

Description: Asphalt Concrete Overlay, w/some AC shoulder patching, 4" binder courses (2), 1 1/2" wearing course over existing PCC and CRCP, one interchange included.

Bridges: 1. No work, 3 pair of existing bridges (140', 1,780', 175' in length.)

Other Significant Comments: 1. Statewide 45 mph speed limit, during construction.

Study Project - Louisiana #C4
Asphalt Concrete Overlay

Method of Traffic Control: Single Lane Closure, Drums

Route: Interstate 12 **Fed. Proj.** IR-12-1(078)040
State Proj. 454-03-21

Location: Tangipahoa Parish, Hammond to St. Tammany Parish Line

Project Length: 12.862 miles **Average Daily Traffic** - 21,610

Construction Costs: Total - $ 1,294,622
Traffic Control - $ 35,000 (2.5 %)
Alternate - $ 689,840

Construction Period: Started - 1/27/86
Completed - 7/17/86

Description: Asphalt Concrete Overlay, Cold Planing (2 5/8") with AC wearing course (2"), three interchanges included.

Bridges: 1. No work, 10 pair bridges, from 195' to 773' in length

Other Significant Comments: 1. Statewide 45 mph speed limit during during construction.

Study Project - Michigan #C10
Asphalt Concrete Overlay

Method of Traffic Control: Single Lane Closure.

Route: Interstate 96 **Fed. Proj.** I-96-3(119)107
State Proj. 25203A

Location: Ingham County, Southeast of Lansing, just east of US 127

Project Length: 5.88 miles **Average Daily Traffic** - 24,500

Construction Costs: Total - $ 1,643,603
Traffic Control - $ 38,042 (2 %)
Alternate - $ 449,405

Construction Period: Started - 10/8/86
Completed - 8/21/87

Description: Asphalt Concrete Overlay, over Existing 8" PCC, 4" Asphalt Concrete Pavement and Shoulders in 3 courses, Some additional superelevation feathered, Spot PCC repair, Guard Rail. One interchange.

Bridges: None.

Other Significant Comments: 1. Legislative Speed Limit 45 mph.
2. Some curves superelevation increased.

Study Project - North Carolina # C3
Asphalt Concrete Overlay

Method of Traffic Control: Single Lane Closure, Iowa Weave

Route: Interstate 85 **Fed. Proj.** IR-85-2(31)42
State Proj. 8.1671501
TIP # I-2107

Location: Mecklenberg County, North Charlotte, US 29 - NC 49 Connector to Cabarrus County Line.

Project Length: 6.004 miles **Average Daily Traffic** - 30,000

Construction Costs: Total - $ 3,437,750
Traffic Control - $ 356,388 (10 %)
Alternate - $ 759,445

Construction Period: Started - 7/13/87
Completed - 11/2/88

Description: Asphalt Concrete Overlay (2" + 2"), Concrete Pavement Patching (8"), resurface shoulder drains, thermoplastic markings, signing. Two interchanges.

Bridges: 1. A pair of structures, 197' in length. No work included.

Other Significant Comments:
1. Max. lane closure for concrete repairs limited to 1/2 mile.
2. Max. lane closure 2 1/2 miles, min. distance between closures 2 miles.
3. Peak hour lane closure restrictions 6AM - 8PM on Fridays.
4. Temp. loop detectors used to locate errant vehicles with warning alarm to alert workers. Also used to locate queues and variable message signs. Ineffective. False actuations by contractor equipment. Relocation of detection equipment cumbersome.
5. Iowa weave provided to slow vehicles approaching lane closures. Found to be vary effective.

Study Project - North Carolina # C17
Asphalt Concrete Overlay

Method of Traffic Control: Single Lane Closure, Drums

Route: Interstate 85 **Fed. Proj.** IR-85-3(110)126
State Proj. 8.1491001

Location: Guilford County, East of Greensboro, NC 3032 to east of NC 61

Project Length: 11.820 miles **Average Daily Traffic** - 41,300

Construction Costs: Total - $ 2,607,689
Traffic Control - $ 155,501 (6 %)
Alternate - $ 1,471,519 (AC Divider)

Construction Period: Started - 7/30/85
Completed - 12/14/86

Description: Asphalt Concrete Overlay. Minor milling (2") under bridges, patched existing PCC w/AC, resurfacing (2" AC) and thermoplastic pavement markings. 5 interchanges.

Bridges: 1. One pair of structures, no work identified.

Other Significant Comments:
1. Lane closures maximum 2 miles, distance between minimum 1 mile.
2. Field problems w/lane closures.

Study Project - Oregon # C6
Asphalt Concrete Overlay

Method of Traffic Control: Single Lane Closure, Cones; TLTWO under 2 bridges raised only, Temporary Concrete barrier

Route: Interstate 84 **Fed. Proj.** IR-84-6(14)237
State Proj.

Location: Umatilla and Union Counties, Meacham to Hilgard

Project Length: 18.39 miles **Average Daily Traffic** - 5,550
(3 mile gap in work)

Construction Costs: Total - $ 6,824,651
Traffic Control - $ 568,358 (8 %)
Alternate - $ 972,454 (TLTWO/TCB entire project)

Construction Period: Started - 4/29/86
Completed - 10/31/86

Description: Asphalt Concrete Overlay, milling (2"), base course (2") and wearing course (2"), grading, bridges (6 joint repairs, 2 over I-84 raised clearance). Not permanent pavement improvement (additional surface course in future). Three interchanges. Median width 8.4' to 240'.

Bridges: 1. Two pairs of structures, 153' & 425' in length, two single structures, 121' & 164' in length. (Two structures over I-84 raised 2'-1" and 1'-1", 164' & 220' in length.)

Other Significant Comments:
1. Milling was not continuous, but only where pavement rutted in outside lane
2. Significant increase in general excavation quantities/cost. (Doubled)
3. Material milled recycled for use on other project.
4. Temporary concrete barrier State policy for TLTWO for liability reasons.

Study Project - Oregon # C8
Asphalt Concrete Overlay

Method of Traffic Control: Single Lane Closure, Cones(?)

Route: Interstate 84 **Fed. Proj.** IR-84-2(21)042
State Proj.

Location: Hood River County, East of Portland, Eagle Creek to Mitchell Point

Project Length: 16.89 miles **Average Daily Traffic** - 12,425 (Avg)

Construction Costs: Total - $ 366,192
Traffic Control - $ 13,370 (3.5 %)
Alternate - $ 628,430 (TCB)

Construction Period: Started - 4/16/87
Completed - 8/31/87

Description: Asphalt Concrete Overlay, Intermittant pavement milling (2"), partial wearing course (2"), recessed pavement markers. No interchanges.

Bridges: 1. Nine structures, no work identified.

Other Significant Comments:
1. 1.2 mile gap in work.
2. 45 mph speed zone.
3. Overlay on outside lanes only.

Study Project - Utah # C3
Asphalt Concrete Overlay

Method of Traffic Control: Single Lane Closure, Drums

Route: Interstate 15 **Fed. Proj.** IR-15-4(29)145
State Proj.

Location: Millard County, Baker Canyon to Meadow

Project Length: 15.344 miles **Average Daily Traffic** - 4543 (Avg.)

Construction Costs: Total - $ 2,813,652
Traffic Control - $ 82,641 (3 %) (See Comment 3)
Alternate - $ 652,340 (Drums)

Construction Period: Started - 5/5/87
Completed - 7/18/87

Description: Asphalt Concrete Overlay, intermittent milling varies (1", 2 1/2", 5 1/2"), AC Pavment (2 1/2", 5 1/2"), 1" Sealcoat entire project. Two interchanges, one pair of rest areas. Median width approximately 64'.

Bridges: 1. None.

Other Significant Comments:
1. Lane closures limited to 3 miles max.
2. Extensive additional 2 1/2" milling.
3. Partial maintenance of traffic cost within Mobilization, Lump Sum.

Study Project - Kentucky #D7
Bridge Deck Overlay

Method of Traffic Control: Single Lane Closure, Drums or Typ.II Bar.

Route: Interstate 75 **Fed. Proj.** IR-75-1(47)14

Location: Whitely & Laurel Counties, Cumberland & Laurel Riv. Brdgs

Project Length: 0.218 mile **Average Daily Traffic** - 26,000

Construction Costs: Total - $ 493,862
Traffic Control - $ 19,500 (4 %)
Alternate - $ 219,055

Construction Period: Started - 11/3/86
Completed - 6/27/87

Description: Emergency Temporary Repairs to two pairs of Interstate 75 bridges, floorbeam strengthening, abutment bearing stiffeners, floorbeam knee modifications, expansion dams.

Bridges: 1. Two bridge structures, 485.50' and 669.6' with 30' decks.

Other Significant Comments: 1. Separate pavement rehabilitation contractor working adjacent.
2. Traffic Control - Lump Sum

Study Project - Michigan #D5
Bridge Deck Overlay

Method of Traffic Control: Single Lane Closure w/ concrete barrier

Route: Interstate 196 **Fed. Proj.** IR-196-5(152)2
State Proj. 24322A

Location: Berrien & Van Buren Counties north of Benton Harbor

Project Length: 0.08 miles **Average Daily Traffic** - 11,400

Construction Costs: Total - $ 520,432
Traffic Control - $ 122,408 (24 %)
Alternate - $ 497,757

Construction Period: Started - 7/30/86
Completed - 11/8/86

Description: Bridge Deck Overlays & Bridge Painting, Three pairs of bridges. Latex modified overlays, asphalt concrete approach wedges, no parapet work.

Bridges: 1. One pair, 201' in length, 38'- 6" in width.
2. One pair, 123'-9" in length, 42'- 6" in width.(Coloma Rd.)
3. One pair, 108'- 3 1/8" in length, 39'- 6" in width. (32nd Avenue).

Other Significant Comments: 1. Legislative Speed Limit 45 mph.
2. Concrete Barrier used for protection.

Study Project - West Virginia # D3
Bridge Deck Overlay

Method of Traffic Control: Single Lane Closure, Drums

Route: Interstate 64 **Fed. Proj.** IR-64-1(144)1
State Proj. S350-64-1.25

Location: Wayne County, Southwest of Huntington, Kenova Bridges

Project Length: 0.69 miles **Average Daily Traffic** - 19,000

Construction Costs: Total - $ 174,585
Traffic Control - $ 19,978 (11 %)
Alternate - $ 262,500 (TCB)

Construction Period: Started - 10/14/86
Completed - 11/4/86

Description: Bridge Deck Overlay, Latex Overlay, Median width 40'.

Bridges: 1. One pair, 205'-5 1/2" in length, width 30'.

Other Significant Comments:
1. Shadow vehicle required where workers present.
2. Law enforcement officer required during overlay pours and 2 hours subsequent.

Study Project - West Virginia # D8
Bridge Deck Overlay

Method of Traffic Control: Single Lane Closure, Temporary Concrete Barrier

Route: Interstate 79 **Fed. Proj.** IR-79-1(56)25
State Proj. S344-79-25.79

Location: Roane County, Amma

Project Length: 0.16 miles **Average Daily Traffic** - 6,200

Construction Costs: Total - $ 1,220,779
Traffic-Control - $ 18,417 (1.5 %)
Alternate - $ 473,465 (AC Divider)

Construction Period: Started - 4/21/86
Completed - 9/25/87

Description: Bridge Deck Replacement/Retrofit Structural Steel to stop cracks in steel floor beam connection plates by drilling holes, and providing steel angles bolted to top flange as necessary for stiffening. Deck removal specified for access to perform retrofit work. Latex overlay decks after retrofit. Bridge lateral bracing system removed from one bridge (2682). Median width approx. 40'

Bridges: 1. Two pair, 476' and 370' in length, widths 40'.

Other Significant Comments:
1. Temporary road constructed to carry traffic for lane closures on approaches.
2. One lane traffic maintained during bridge work.

Study Project - Arizona #E2
Bridge Deck Replacement/Widening

Method of Traffic Control: Single Lane Closure (From TLTWO by Change Order proposed by contractor)

Route: Interstate 40   Fed. Proj. IR-40-5(67)

Location: Navajo County, Twin Wash to Apache County Line

Project Length: 4.19 miles   **Average Daily Traffic** - 8,800

Construction Costs: Total - $ 2,558,259
Traffic Control - $ 253,094 (10 %)
Alternate - TLTWO Est. $ 827,210 (TCB entire project)

Construction Period: Started - 5/5/86
Completed - 6/4/87

Description: Asphalt Concrete Overlay (1 1/2" to 2"), Some milling of Westbound Right Lane (2 1/2"), Slopes reshaped, Two bridges included, major structure widening of one pair from 30' to 42' (bridge length 482') dictated traffic control. Conc. Bar. used for SLC at bridges

Bridges:
1. Over Big Lithendendron Wash (#541/#542), length 481.92' Widened from 30' to 42'-1 1/2"
2. Over Amanda T.I. Road (#543/544), length 29' Width 38'

Other Significant Comments:
1. Change Order altered method of Traffic Control for bridges and the entire project. Prestressed slabs on bridge decks. Savings - $250,000

Study Project - Arizona #E6
Bridge Deck Replacement/Widening

Method of Traffic Control: TLTWO, Concrete Barrier

Route: Interstate 10   Fed. Proj. IR-10-6(103)

Location: Cochise County, Ocotillo Road TI

Project Length: 0.20 miles   **Average Daily Traffic** - 12,000

Construction Costs: Total - $ 1,681,428
Traffic Control - $ 357,135 (21 %)
Alternate - N/A (Bridges replaced)*

Construction Period: Started - 10/12/86
Completed - 6/1/87

Description: Replacement of two interchange bridge structures including approaches and guard rail because of foundation settlement problem.

Bridges: 1. Over Ocotillo Road (#2044/2045), length 101', width 42' New structures prestressed box beam type

Other Significant Comments:
1. Ocotillo Road closed under I-10 during removal/construction of bridges.

*2. Alternative TCP would have been to close I-10 interchange bridges and detour all I-10 traffic on ramps with crossroad traffic stopped at exit ramps.

3. Total construction cost reflects $40,000 incentive payment ($4,000 per day) for 10 day early completion.
4. All contractors submitting bids furnished identical unit prices for bidding traffic control.

Study Project - Louisiana #E1
Bridge Deck Replacement/Widening

Method of Traffic Control: TLTWO, Flexible Tubes, Ceramic Markers

Route: US Route 190 Huey B. Long Bridge — **Fed. Proj.** BHF-03-1(009) **State Proj.** 007-10-28

Location: East and West Baton Rouge Parishes, Baton Rouge, Mississipi River Bridge

Project Length: 1.19 miles — **Average Daily Traffic** - 16,000, 9 trains

Construction Costs: Total - $ 15,020,322 (Incomplete Final Costs)

Traffic Control - $ 544,540 (3.5 %)
Alternate - N/A, Close each bridge*

Construction Period: Started - 5/27/86
Completed - 12/88 (?)

Description: Deck Replacement/Widening & Metal Work to repair structural deficiencies, Concrete Repairs, Each pair lanes widened, 19'9" to 24'.

Bridges: 1. 5,879' length, combination 4 lane divided with RR Tracks in median. Each pair of lanes widened from 19'9" to 24'.

Other Significant Comments:

1. All truck traffic detoured during construction over Interstate 110 to Interstate 10 with directional routing on Routes 1 and 415 (west of Mississippi River)

*2. Alternate TCP Analysis
   a. Lane Closure not practical - Exstg. Deck 19'-9" (2 Lanes)
   b. Other Alt. would be to close one bridge and use other for directional traffic. Would require detour for all opp. dir. to I-10 including trucks.
   c. Excessive user costs for alt. No feasible alternative.

3. Extensive Flex. Tube replacement on TLTWO. 3300 (116 bid) @ $50.00 for total replacement cost $165,000

Study Project - North Carolina # E9
Bridge Deck Replacement/Widening

Method of Traffic Control: TLTWO, Raised Asphalt Divider w/tubes

Route: U. S. Route 1 Southbound Only — **Fed. Proj.** BRF-43-3(12) **State Proj.** 8.1401001

Location: Wake County, Raleigh, Bridge over Neuse River

Project Length: 0.104 miles — **Average Daily Traffic** - 15,000

Construction Costs: Total - $ 879,999
Traffic Control - $ 71,368 (8 %)
Alternate - $ 103,000 (Detour)* SLC not feasible

Construction Period: Started - 12/9/85
Completed - 7/31/87

Description: Bridge deck & structural repairs, parapet repairs, drainage. Southbound bridge structure only.

Bridges: 1. One bridge, 295.081'

Other Significant Comments:

* 1. Alternate design analysis by State estimated cost of $103,000 for detour.
2. Bridge deck width narrowed from 37.4' to 36'
3. Project involves work on Southbound structure only.
4. 45 mph Speed Limit during construction.

Study Project - West Virginia # E5
Bridge Deck Replacement/Widening

Method of Traffic Control: TLTWO, Temporary Concrete Barrier

Route: Interstate 64 **Fed. Proj.** IR-64-1(137)41
State Proj. S340-64-41.51

Location: Putnam County, West of Charleston & US 35/Kanawha River, over CR 29, Rock Step Run Creek & CR33/5 and river

Project Length: 0.886 miles **Average Daily Traffic** - 27,000

Construction Costs: Total - $ 2,567,684 (Award)
Traffic Control - $ 709,449 (28 %)
Alternate - N/A Not practical w/o detour.

Construction Period: Started - 11/12/87
Completed - Early 1989

Description: Bridge Deck Widening/Rehabilitation. Replace decks, structural steel, parapets & piers, repair approach slabs, drainage, grading & temporary lighting. Median width 40'.

Bridges: 1. Two pair, 128.31' and 285.25 in length. Widen from 37'-0" to 38'-6", and 30'-0" to 39'-4" respectively.

Other Significant Comments:
1. Field delay studies.
2. Existing median crossovers used, then to be removed with project.
3. TLTWO WB I-64 implemented 12/11/87.
4. TLTWO switched to EB I-64, 8/26/88.
5. Substantial problems with deck/structural repairs EB Structures and length of time for TLTWO WB.
6. Traffic returned to normal flow in December, 1988, Single Lane Closure used January, 1989 to remove crossovers.

Study Project - West Virginia # E6
Bridge Deck Replacement/Widening

Method of Traffic Control: TLTWO, Temporary Concrete Barrier

Route: Interstate 77 **Fed. Proj.** IR-77-3(165)119
State Proj. S318-77-119.26

Location: Jackson County, North of Charleston, Spicewood Creek Bridge

Project Length: 0.598 miles **Average Daily Traffic** - 9,300

Construction Costs: Total - $ 1,041,904
Traffic Control - $ 315,922 (30 %)
Alternate - N/A SLC Alternate not practical w/o detour.

Construction Period: Started - 10/20/86
Completed - 11/6/87

Description: Bridge Deck Replacement/Widening, Replace decks, structural steel, parapets & piers, repair approach slabs, drainage, grading.

Bridges: 1. One pair, 150.00' in length. Widen decks from 37'-0" to 38'-6"

Other Significant Comments:
1. TLTWO switched from NB to SB structures week of 6/1/87.
2. Alternate TCP not practical w/o detour.

Study Project - Kentucky #F9
Reconstruction

Method of Traffic Control: TLTWO, Tubes, Lane Tape

Route: Western Kentucky Parkway State Proj. SSP 092-9001 082-085

Location: Ohio County

Project Length: 1.698 miles **Average Daily Traffic** - 4,200

Construction Costs: Total - $ 1,364,803
Traffic Control - $ 172,161 (13 %)
Alternate - N/A Landslide Repair.

Construction Period: Started - 10/7/86
Completed - 9/15/87

Description: Land Slide Repair to three sections of highway, Break and Seat.

Bridges: 1. None

Other Significant Comments:
1. TLTWO only option for handling traffic
2. Nearly one-half of project cost is embankment in place ($547,344 for 121,632 CY @ $4.50)

Study Project - Louisiana #F6
Reconstruction

Method of Traffic Control: TLTWO, Flexible Tubes, Ceramic Markers

Route: Interstate 59 **Fed. Proj.** IR-59-1(019)5
State Proj. 453-01-28

Location: St. Tammany Parish, W. Pearl River to Mississipi St. Line

Project Length: 5.537 miles **Average Daily Traffic** - 12,980

Construction Costs: Total - $ 10,649,517 (Incomplete Final Costs)
Traffic Control - $ 900,438 (8.5 %)
Alternate - N/A Bridge widening work precludes single lane closure (Existing bridges 28' wide.)

Construction Period: Started - 2/19/86
Completed - 89% as of 10/11/88 (74 % time)

Description: Complete Reconstruction, Removal existing PCC/Surface courses, New PCC (12") on AC base (2"), Widening 6 pairs of bridges.

Bridges: 1. Widen 6 pairs of bridges, 160' to 400' in length, widened from 28' to 40' width.

Other Significant Comments:
1. Decision on TLTWO for reconstruction prompted bridge widening while one half of freeway closed.
2. Some time lost by widening bridges first during good weather.
3. Speed limit 45 by statute during construction.
4. Extensive tube replacement (11,168). Alternate TLTWO using AC Divider would have been more economical. (Est. $210,761, AC Divider, vs $476,550 for tube replacement alone)

AC Divider Est. = $3.15/Ft x 11.074 mi. x 5280 = $184,166
591 x $45 (Tube replacement) = 26,595
TOTAL $210,761

Study Project - Louisiana #F7
Reconstruction

Method of Traffic Control: TLTWO, Paddles & ceramic markers

Route: Interstate 20 **Fed. Proj.** IR-20-1(160)042
State Proj. 451-03-37

Location: Webster Parish, McIntyre to Dixie Inn

Project Length: 2.681 miles **Average Daily Traffic** - 27,590

Construction Costs: Total - $ 5,048,848
Traffic Control - $ 698,387 (14 %)
Alternate - N/A Bridge widening work precludes single lane closure (Existing bridges 26' wide.)

Construction Period: Started - 2/10/86
Completed - 6/25/87

Description: Complete reconstruction, removed PCC (10"), sand blanket (2") & soil cement (6"), new 13" PCC on 2" AC base course and 6" subbase treatment, widen one pair of bridges from 26' to 40'. Includes one interchange.

Bridges: 1. One pair of bridges, 160' in length, widened from 26' to 40'

Other Significant Comments:
1. Separation devices initially installed were flat cross section and were blown over by passing trucks, replaced with flexible tubes.
2. Speed limit 45 by statute during construction.
3. Right lane construction 15' width with 7' paved shoulder.

Study Project - Louisiana #F9
Reconstruction

Method of Traffic Control: TLTWO, Raised Asphalt Divider, Flexible Posts (Paddle Type)

Route: Interstate 20 **Fed. Proj.** IR-20-3(085)137
State Proj. 451-07-30

Location: Richland Parish, Rayville to Holly Ridge

Project Length: 6.780 miles **Average Daily Traffic** - 13,530

Construction Costs: Total - $ 10,111,189
Traffic Control - $ 887,875 (9 %)
Alternate - N/A Existing bridges 26' wide.

Construction Period: Started - 9/12/85
Completed - 6/19/87

Description: Complete reconstruction, removed PCC (10" continuously reinforced) and subbase, new 18" AC pavement with a wearing course (1 1/2"), AC binder course (4"), on AC base course (12 1/2") and subbase treatment (6"). Includes two interchanges.

Bridges: 1. Two pair of bridges, 150' in length, 26' width, no work identified

Other Significant Comments:
1. Alternate TCP for Single Lane Closure impractical because of existing 24' width of PCC continuously reinforced concrete to be removed.
2. Speed limit 45 by statute during construction.
3. Right lane construction 15' width with 7' paved shoulder.
4. Significant replacement of impact attenuators during construction.

Study Project - Louisiana #F15
Reconstruction

Method of Traffic Control: TLTWO, Flexible post (paddle), ceramic markers.

Route: Interstate 20 **Fed. Proj.** IR-20-2(060)86
State Proj. 451-05-59

Location: Lincoln Parish, Ruston to Choudrant Highway

Project Length: 7.207 miles **Average Daily Traffic** - 23,870

Construction Costs: Total - $ 11,947,245
Traffic Control - $ 1,040,073 (9 %)
Alternate - $ 876,780

Construction Period: Started - 12/16/85
Completed - 2/1/88

Description: Complete reconstruction, removed PCC pavement (10"), sand blanket (2") and soil cement (6"), new PCC (13") on AC base course (2") and subbase treatment (6"). Includes 2 interchanges. Right lane width = 15'.

Bridges: 1. At least one pair. Length/Width not determinable from construction plans.

Other Significant Comments:
1. Speed limit 45 by statute during construction.
2. Right lane construction 15' width with 7' paved shoulder.
3. Alternate TCP for Single Lane Closure will lengthen time of work an indeterminable amount of time.
4. Extensive damage to tubes prompted additional enforcement during constr.

Study Project - Michigan #F6
Reconstruction

Method of Traffic Control: TLTWO, Raised Asphalt Divider, Tubes

Route: Interstate 96 **Fed. Proj.** IR-96-2(130)54
State Proj. 24662A

Location: Kent & Ionia Counties, Northwest of Clarksville

Project Length: 8.2 miles **Average Daily Traffic** - 12,800

Construction Costs: Total - $ 8,304,603
Traffic Control - $ 394,681 (5 %)
Alternate - $918,630*

Construction Period: Started - 3/17/87
Completed - 11/13/87

Description: Concrete Pavement & Asphalt Shoulder Reconstruction, Recycling, Safety Upgrading. Remove & Recycle 9" RCP & remove 3" Subbase, & add RCP (9") on Open Graded Drainage Course (4"). Includes one interchange.

Bridges: 1. One pair of bridges over C & O RR. Approx. 170' in length by 38' wide, skewed. No work involved.

Other Significant Comments:
1. Legislative Speed Limit 45 mph.
2. 2nd coat paint on bit. divider.

* 3. Alternate Lane Closure not economically feasible. Analysis performed to verify.

Study Project - Michigan #F8
Reconstruction

Method of Traffic Control: TLTWO w/asphalt divider

Route: Interstate 94 **Fed. Proj.** IR-94-2(102)59
State Proj. 24755

Location: Van Buren & Kalamazoo Counties, Paw Paw to Mattawan

Project Length: 5.97 miles **Average Daily Traffic** - 18,500

Construction Costs: Total - $ 7,638,414
Traffic Control - $ 406,969 (5.5 %)
Alternate - $1,588,884 *

Construction Period: Started - 5/19/87
Completed - 6/16/88

Description: Concrete Pavement & Shoulder Reconstruction, Recycling. Remove & Recycle 9" RCP & remove 3" Subbase, & add RCP (10") on Open Graded Drainage Course (4"). Includes two interchanges.

Bridges: 1. One pair of bridges over Paw Paw River. Length, 145' -8", width, 44'. No work.

Other Significant Comments:
1. Legislative Speed Limit 45 mph.
2. Alternate Lane Closure not feasible.
3. Retro-reflectometer bid to check construction signs. ($2,700)
4. Existing crossovers (4) constructed in previous project. Two removed, 2 retained after construction. ($24,350 each avg. cost for removal.)
5. * Alternate Lane Closure not economically feasible. Analysis performed to verify.

Study Project - North Carolina #F1
Reconstruction

Method of Traffic Control: Single Lane Closure, Drums, Conc. Barr. at Bridges.

Route: Interstate 40 **Fed. Proj.** IR-40-1(97)4
State Proj. 8.1940204, TIP I-806/807/808A

Location: West of Ashville, MP 4 to NC 1366

Project Length: 18.431 miles **Average Daily Traffic** - 15,000

Construction Costs: Total - $ 9,135,648
Traffic Control - $ 977,682 (10.5 %)
Alternate - $ 1,516,804

Construction Period: Started - 9/17/84
Completed - 6/3/87

Description: Asphalt Overlay, Milling & Recycling (4"-6"depth), Safety Upgrading, Remove & Replace Conc. Median Bar., Structure Rehab. (6), Signing, Thermoplastic Markings, Plowable RPM's. Includes 3 interchanges, 2 tunnels, one Welcome Center/Rest Area. Mountainous terrain.

Bridges: 1. Six single bridge structures. Lengths vary 163' to 611', widths vary 58' to 74'.

Other Significant Comments:
1. Legislative Speed Limit 45 mph.
2. Lane closure length max. 4 miles, min. between closure 1 mi. same dir.
3. TCP problems w/Lane closures. Extensive changes, improvements made.
4. Extent of milling added $1 M by C.O. Bid 3"-3.5", Actual 4"-6" required.
5. Pavt. Dropoff problem, w/milling
6. Six feet median typical for majority of project length.

Study Project - North Carolina #F2
Reconstruction

Method of Traffic Control: TLTWO (Conc. Bar.) & Lane Closure (Drums)

Route: Interstate 40 **Fed. Proj.** IR-40-1(99)23
State Proj. 8.1940205, TIP #I-908B/808B

Location: Haywood & Buncombe Counties, West of Ashville, NC 1366 to NC 1200, Adjacent to and east of Project F1

Project Length: 14.234 miles **Average Daily Traffic** - 25,000

Construction Costs: Total - $ 9,523,144 (98 % Compl. Cost)*
Traffic Control - $ 934,015 (*) (10 %)
Alternate - $ 1,197,550* (NC perfrmd alt. anal.)

Construction Period: Started - 12/9/85
Completed - 6/22/88

Description: Asphalt Overlay, Milling & Recycling (1"-3"depth), Safety Upgrading, Remove & Replace Conc. Median Bar., Structure Rehab. (6), Signing, Thermoplastic Markings, Plowable RPM's. Includes 4 interchanges. Mountainous terrain.

Bridges: 1. Five single, plus one pair of bridge structures. Lengths vary 134' to 213', widths 68' on single structures and 28' on the pair of bridges.

Other Significant Comments:
1. Legislative Speed Limit 45 mph.
2. Lane closure length max. 4 miles, min. between closure 1 mi. same dir.
3. TCP worked well. Traffic Control Unit performed alt. TCP analysis in design
4. Milling changed from 2" & 1.5" to 3" & 1" during constr.
5. Pavt. Dropoff problem, w/milling
6. Six feet median typical for majority of project length.

*7. Movable Concrete Barrier as Alternate

Study Project - North Carolina # F4
Reconstruction

Method of Traffic Control: TLTWO, with Raised Asphalt Divider, tubes

Route: Interstate 40 **Fed. Proj.** IR-40-2(82)77
State Proj. 8.1870203
TIP # I-810

Location: McDowell County, Between Marion and Morganton

Project Length: 8.955 miles **Average Daily Traffic** - 17,000

Construction Costs: Total - $ 6,416,317 (Award *, 55 % Compl.)
Traffic Control - $ 1,112,589 (17 % *)
Alternate - $ 1,684,063 (Transp. Conc. Bar.)

Construction Period: Started - 1/28/88
Completed - 55 % (12/21/88), Est. 12/89

Description: Reconstruction. Concrete rehab., Asphalt Overlay, Guard Rail, Erosion Control & Landscaping, Thermoplastic Markings, Signing. Three interchanges & Pair of Rest Areas. Median width 36'. Mountainous Terrain.

Bridges: 1. Pair of structures, 124.58' in length. 4" asphalt overlay with parapet/rail raised.

Other Significant Comments:
1. Construction progressing with no significant problems.
2. 21 % commercial vehicles.
3. Contractor not permitted to work on opposite sides of freeway concurrently.
4. West crossovers to be left in place for use on adjacent project.
5. Incentive/Disincentive clause
6. Access maintained for interchanges and rest areas. Common median cross-over used for both directions of TLTWO. Temporary AC in entire median for 650' for cross-overs.

Study Project - North Carolina # F5
Reconstruction

Method of Traffic Control: Single Lane Closure, Movable portable concrete barrier

Route: Interstate 77 **Fed. Proj.** IR-77-1(103)14
State Proj. 8.1671701

Location: Mecklenberg County, Charlotte, from I-85 north to NC 2004

Project Length: 9.228 miles **Average Daily Traffic** - 32,000

Construction Costs: Total - $ 5,472,109 (98 % Compl.)
Traffic Control - $ 1,302,858 (24 %)*
Alternate - $ 1,609,404 (AC Divider)

Construction Period: Started - 12/3/87
Completed - 98 % (1/13/89)

Description: Reconstruction. Concrete pavement repair, Asphalt concrete pavement overlay (2" + 2") and shoulders, bridge rail strengthening, shoulder drains, thermoplastic markings. Three interchanges. Median width approximately 100'.

Bridges: 1. One pair of structures, 124'-7" in length. Concrete and metal railings repaired and heightened.

Other Significant Comments:
1. "Quick Change" Movable Concrete Barrier & Transporter Equipment used & furnished to NC DOT after completion.
2. 29 % Commercial traffic.
3. Minimum 2 miles between lane closures
4. No closures, 6-9:30AM SB, 3 - 7PM NB, between 6AM - 8PM Fridays.

*5. Transporter Cost - $185,000. 8006' of TCB @ $70.00/LF = $506,420. Remove and Reset 80,618' @ $3.00/LF. = $241,854.

Study Project - Arizona # G7
New/Interchange Construction

Method of Traffic Control: Single Lane Closure/Concrete Barrier

Route: Interstate 10 **Fed. Proj.** IR-10-5(60)

Location: Pima County, Tucson, Kino Interchange

Project Length: 2.11 miles **Average Daily Traffic** - 33,000

Construction Costs: Total - $ 3,085,206
Traffic Control - $ 375,802 (12 %)
Alternate - $ 252,400

Construction Period: Started - 5/27/86
Completed - 5/19/87

Description: Addition of 5 interchange ramps to partial interchange to provide all traffic movements and a complete interchange.

Bridges: 1. New bridge for ramp over Ajo Way, Length 176', Width 26'. Eastbound and Westbound I-10 bridges widened. Length 85', EB widened from 38' to 64', WB 38' to 50'

Other Significant Comments:
1. Field delay study performed 2/9-10/87
2. Apparent Incentive/Disincentive Clause, but no bid tabulation record of payment or penalty.

Study Project - Florida #G5
New/Interchange Construction

Method of Traffic Control: TLTWO on Existing 2-Lane Highway

Route: Florida State Route 95 (US 26) **State Proj.** No.48060-3515

Location: Escambia County, CR 4A (Bluff Springs Rd.) - CR 4 West

Project Length: 3.024 miles **Average Daily Traffic** - 4,900

Construction Costs: Total - $ 5,610,988
Traffic Control - $ 151,636 (3 %)
Alternate - N/A (Used Existing Highway)

Construction Period: Started - 7/14/86
Completed - 2/2/88

Description: Existing Two Lane Highway, New Additional Pair Lanes, Resurface Existing Pair (0.55 Mi.) (New Additional Pair of Lanes (1.26 Mi.), Partial made 5 lanes undivided (1.21 Mi.). Asphalt Concrete (3" + 5/8")

Bridges: 1. None, three culverts, 26' long

Other Significant Comments: 1. Project construction/traffic control not uniform and difficult to use for comparative purposes.

Study Project - Kentucky #G1
New/Interchange Construction

Method of Traffic Control: TLTWO with Cones (Daily Install/Remove) /Single Lane Closure

Route: Interstate 75 **Fed. Proj.**
State Proj. ED 63-4

Location: Scott County, North of Lexington, Delaplain Rd. Intge., KY 620

Project Length: 0.398 miles **Average Daily Traffic** - 23,000

Construction Costs: Total - $ 2,409,566
Traffic Control - $ 122,040 (5 %) (includes est. cost of $71,040 for median cross-overs constructed previously in separate project)
Alternate - N/A (Daily frwy. closure using interchange ramps for traffic maintenance. Bridge overpass construction precludes single lane closure alternate.)

Construction Period: Started - 2/2/87
Completed - 10/14/87

Description: Interchange Reconstruction, Widen interchange overpass structure deck from 2 to 5 lanes, including additional pier construction, widening ramps, roadway lighting, two traffic signals and signing.

Bridges: 1. Interchange overpass structure over Interstate 75 widened from 2 to 5 lanes plus shoulders (82' overall width) with existing deck removed, new piers constructed.

Other Significant Comments: 1. Unique TLTWO on Interstate 75 during bridge work with daily installation and removal of cones for channelization and TLTWO. Work permitted from 7:00 AM, Monday through Friday Noon during daylight hours, and excluding specified holiday periods. TLTWO used for 22 days.
2. Single lane closures permitted on outside lanes for construction of ramp terminals and piers during periods specified above.
3. Project constructed for new Toyota Auto Plant.

Study Project - Michigan #G3
New/Interchange Reconstruction

Method of Traffic Control: TLTWO, Concrete Barrier by C.O. on US 127

Route: Interstate 69 **Fed. Proj.** I-69-3(061)89
State Proj. 24681A

Location: Clinton County, Lansing, N. of Clark Rd. to W. of Chandler Rd.

Project Length: 2.02 miles **Average Daily Traffic** - 15,500 (US 127)

Construction Costs: Total - $ 15,976,716 (Final Costs Incomplete)
Traffic Control - $ 296,642 (2%)
Alternate - $ 100,552 *

* Contractor proposed TLTWO by Change Order at no cost to State, which was used instead of Single Lane Closure original bid.

Construction Period: Started - 9/28/85
Completed - (1988)

Description: New/Interchange Construction, Three bridges & Culvert. Study is for maintaining traffic on US 127.

Bridges: 1. None on US 127

Other Significant Comments:
1. Legislative Speed Limit 45 mph.
2. Study is for US 127 for the period 9/28/85 to 12/19/86. TLTWO was used 5/13/86 - 12/19/86 during interchange construction on approx. 2 miles.
3. Single Lane Closure on US 127 required in original plans. Change Order requested by contractor at no cost to State to provide TLTWO with State requiring concrete barrier separation. Contractor estimate for TLTWO was + $ 175,241, with no cost to the State.

Study Project - North Carolina # G13
New Construction/Interchange

Method of Traffic Control: Single Lane Closure, Concrete Barrier

Route: Interstate 40 **Fed. Proj.** IR-40-4(74)282
State Proj. 8.1350401
TIP # I-1026

Location: Durham County, Raleigh, Interchange w/NC 1959 (South Miami Boulevard) near Research Triangle Park,.

Project Length: 2.703 miles **Average Daily Traffic** - 30,000

Construction Costs: Total - $ 5,892,592
Traffic Control - $ 512,974 (9 %)
Alternate - $ 1,111,150

Construction Period: Started - 7/28/86
Completed - 6/16/88

Description: Partial Interchange Construction, grading, drainage, structures, signing, pavement markings, temporary traffic signals. Two interchanges, one partial interchange.

Bridges: 1. One bridge, 164' in length. New structure over NC 1973

Other Significant Comments:
1. Maximum lane closure 1 mile, minimum 1/2 mile between lane closures.
2. I-40 lane/narrowing time restrictions (6AM - 8PM), peak hour restrictions on Miami Boulevard.
3. Temporary and permanent traffic signals.

Study Project - Utah # GC
New/Interchange Construction

Method of Traffic Control: TLTWO, Drums (Used Existing 2-Lane Hwy.)

Route: Interstate 84 **Fed. Proj.** I-84-5(7)29
State Proj.

Location: Box Elder County, West Tremonton to Blue Creek Summit

Project Length: 14.147 miles **Average Daily Traffic** - 3,845 (Avg)

Construction Costs: Total - $ 21,346,357
Traffic Control - $ 749,244 (3.5 %)
Alternate - N/A (Used Existing 2-Lane Highway)

Construction Period: Started - 12/10/83
Completed - 12/6/86

Description: Started - New Construction of Two additional lanes to existing 2 lane 2-way highway. PCC (10"), Drainage, grading, structures, signing, stock trails.

Bridges: 1. None on I-84

Other Significant Comments:
1. Significant TCP cost in Mobilization.
2. Substantial cost increase for flaggers. Mobilization cost doubled.
3. TLTWO utilized on new pavement during upgrading of existing to interstate standards.

APPENDIX B

FIELD STUDY PROJECTS - INSTRUCTIONS/PROCEDURES

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TRAFFIC FIELD STUDY FORMS

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GENERAL INFORMATION
FIELD DATA COLLECTION

DTFH61-86-C-00064
Construction Costs & Safety Impacts of Work Zone
Traffic Control Strategies
E. N. Burns & C. L. Dudek

Background

The purpose of the studies at the highway construction work zones is to collect traffic data in order to evaluate the effects that the construction has on traffic. The results of the studies will be used to establish guidelines for the entire country. Therefore it is extremely important that your measurements and counts are accurate. You must take extreme care to assure that the data you collect are accurate.

Types of Work Zones

You will be collecting data at two types of highway work zones:

1. Single Lane Closures, and
2. Two-Lane, Two-Way Operation.

Form B1 illustrates examples of Single Lane Closures; Form B2 shows a sketch of a typical Two-Lane, Two-Way Operation traffic control approach.

All of the studies will be conducted at highway work zones on four-lane divided highways. Although the Single Lane Closure or the Two-Lane, Two-Way Operation traffic control approaches can be used on other types of highways, our studies will be made only at work zones on four-lane divided highways where there are two lanes in each direction that are separated by a median divider.

Data Forms

Seven different data recording forms will be used during the studies. A minimum of four forms will be used at each highway construction site.

1. Form A - Used at each site to record information about the construction site

2a. Form B1 - Used only at single lane closure sites to record traffic counts and information about traffic queues (backups)

2b. Form B1-OP1 - Used only at sites with single lane closures in both directions to record traffic counts and information about traffic queues in one direction (Direction 1)

2c. Form B1-OP2 - Used only at sites with single lane closures in both directions to record traffic counts and information about traffic queues in the opposite direction (Direction 2)

2d. Form B2 - Used only at two-lane, two-way operation sites to record traffic counts and information about traffic queues

2e. Form B2 - Used at single lane closure and two-lane, two-way Operation sites to record B2-Ramp traffic counts on entrance (on) and exit (off) ramps

3. Form C - Used at each site to record travel times through the construction zone and the length of the queues

4. Form D - Used at each site to record the number of persons (occupants) in the vehicles on the highway

Data Collection Schedule

It is our intention that data will be collected at two construction sites during a given week. Therefore it may be necessary to travel to a site on a Sunday. Data can be collected during any morning or afternoon peak and during any off-peak period Monday through Friday. In some cases, it may be necessary to collect data on Saturday or Sunday if that is when the peak traffic periods occur.

Contact With Study Supervisor

It is important that you maintain contact with your Study Supervisor before, during, and after data collection at each site.

Prior to leaving home to travel to a study site, your Study Supervisor (Nels Burns or Conrad Dudek) will call you to discuss travel plans and any potential problems (e.g., inclement weather).

After you arrive at a study site and drive through the site to inspect the site conditions, you should telephone your Study Supervisor to discuss the site conditions prior to any data collection.

You should also telephone your Study Supervisor after you complete collecting data at the site and before you leave for the next site or leave for home.

<u>You should telephone your Study Supervisor immediately at any time during data collection at a site if any problems occur.</u>

	Telephone Number
Nels Burns	(614) 888-3094
Conrad Dudek	(409) 823-5106 or (409) 845-1727

Mailing Data

At the end of the week after you have finished collecting data, you should mail all the completed data forms and all data to Conrad Dudek as soon possible. Your Study Supervisor will give you more specific instructions.

Dr. Conrad L. Dudek
2301 Oxford
Bryan, TX 77802.

FIELD DATA COLLECTION INSTRUCTIONS
WEEKDAY PEAK PERIODS
SINGLE LANE CLOSURES

Period of Time

Field data collection can be completed during a 1 1/2-day period for Single Lane Closure traffic control plans when two persons collect data, or during a 1-day period when three or more persons collect data. <u>Note</u>: One additional person must be used for every entrance (on) or exit (off) ramp where traffic counts must be made.

Two-Person Crew

Data must be collected during the a.m. peak, off-peak and p.m. peak periods. Whether you start during the a.m. peak, off-peak or p.m. peak will be determined by the direction of the lane closure. If the lane closure is in the inbound direction, then the studies <u>must</u> begin during the a.m. peak (Schedule A). If the lane closure is in the outbound direction, then the studies <u>must</u> begin either during the p.m. peak (Schedule C) or the off-peak (Schedule B) depending on your travel schedule. Thus the following schedules apply:

Schedule A	Schedule B	Schedule C
1. a.m. peak (day 1)	1. off-peak (day 1)	1. p.m. peak (day 1)
2. off-peak (day 1)	2. p.m. peak (day 1)	2. a.m. peak (day 2)
3. p.m. peak (day 1)	3. a.m. peak (day 2)	3. off-peak (day 2)
4. a.m. peak (day 2)	4. p.m. peak (day 2)	4. p.m. peak (day 2)

During the a.m. and p.m. peak periods, data should be collected for 2 consecutive hours. The a.m. peak period is from 7:00 a.m. to 9:00 a.m. The p.m. peak period is from 4:00 p.m. to 6:00 p.m. Off-peak hours for data collection are between 9:00 a.m. and 3:00 p.m.

The next page identifies the specific studies and the schedule of the studies that must be conducted. The studies and starting periods are dependent upon whether the lane closure is in the inbound or outbound direction.

TWO-PERSON CREW

(Additional persons may be needed to count traffic on the ramps)

<u>Lane Closure In The Direction Of A.M. Peak</u>

1. Day 1: Conduct A.M. Study 1
2. Day 1: Conduct A.M. Study 2
3. Day 1: Conduct Off-Peak Study 1
4. Day 1: Conduct Off-Peak Study 2
5. Day 1: Conduct P.M. Study 1
6. Day 1: Conduct P.M. Study 2

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7. Day 2: Conduct A.M. Study 3
8. Day 2: Conduct A.M. Study 2

<u>Lane Closure In The Direction Of P.M. Peak</u>

1. Day 1: Conduct P.M. Study 1
2. Day 1: Conduct P.M. Study 2

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3. Day 2: Conduct A.M. Study 1
4. Day 2: Conduct A.M. Study 2
5. Day 2: Conduct Off-Peak Study 1
6. Day 2: Conduct Off-Peak Study 2
7. Day 2: Conduct P.M. Study 3

<u>Lane Closure In The Direction Of P.M. Peak</u> (Alternate)

1. Day 1: Conduct Off-Peak Study 1
2. Day 1: Conduct Off-Peak Study 2
3. Day 1: Conduct P.M. Study 1
4. Day 1: Conduct P.M. Study 2

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5. Day 2: Conduct A.M. Study 1
6. Day 2: Conduct A.M. Study 2
7. Day 2: Conduct P.M. Study 3

Three- or More Person Crew

Data must be collected during the a.m. peak, off-peak and p.m. peak periods. It is preferred that data collection start during the a.m. peak period so that data can be collected at a site during one day, eliminating the need to spend a night in a motel or making an extra trip to the work site. However, if necessary, data collection can begin during the off-peak or p.m. peak period. The following schedules apply:

(Preferred)

Schedule A	Schedule B	Schedule C
1. a.m. peak (day 1)	1. off-peak (day 1)	1. p.m. peak (day 1)
2. off-peak (day 1)	2. p.m. peak (day 1)	2. a.m. peak (day 2)
3. p.m. peak (day 1)	3. a.m. peak (day 2)	3. off-peak (day 2)

During the a.m. and p.m. peak periods, data should be collected for 2 consecutive hours. The a.m. peak period is from 7:00 a.m. to 9:00 a.m. The p.m. peak period is from 4:00 p.m. to 6:00 p.m. Off-peak hours for data collection are between 9:00 a.m. and 3:00 p.m.

Page 4 identifies the specific studies and the schedule of the studies that must be conducted.

THREE- OR MORE PERSON CREW
(Additional persons may be needed to count traffic on the ramps)

<u>Lane Closure Studies Beginning During A.M. Peak</u> (Preferred)

1. Day 1: Conduct A.M. Study 1
2. Day 1: Conduct A.M. Study 2
3. Day 1: Conduct A.M. Study 3
4. Day 1: Conduct Off-Peak Study 1
5. Day 1: Conduct Off-Peak Study 2
6. Day 1: Conduct P.M. Study 1
7. Day 1: Conduct P.M. Study 2
8. Day 1: Conduct P.M. Study 3

<u>Lane Closure Studies Beginning During Off Peak</u> (Optional)

1. Day 1: Conduct Off-Peak Study 1
2. Day 1: Conduct Off-Peak Study 2
3. Day 1: Conduct P.M. Study 1
4. Day 1: Conduct P.M. Study 2
5. Day 1: Conduct P.M. Study 3

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6. Day 2: Conduct A.M. Study 1
7. Day 2: Conduct A.M. Study 2
8. Day 2: Conduct A.M. Study 3

<u>Lane Closure Studies Beginning During P.M. Peak</u> (Optional)

1. Day 1: Conduct P.M. Study 1
2. Day 1: Conduct P.M. Study 2
3. Day 1: Conduct P.M. Study 3

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4. Day 2: Conduct A.M. Study 1
5. Day 2: Conduct A.M. Study 2
6. Day 2: Conduct A.M. Study 3
7. Day 2: Conduct Off-Peak Study 1
8. Day 2: Conduct Off-Peak Study 2

SINGLE LANE CLOSURE STUDY DETAILS

A.M. PEAK STUDY 1

Starting at 7:00 a.m., collect two hours of traffic counts on the highway in the direction of the peak traffic flow. This will be at either Location 1+2 or Location 3+4 in the Northbound, Southbound, Eastbound, or Westbound heavy traffic direction, whichever applies (See Form B1).

The counts must be made far enough before (upstream) the construction zone to assure that none of the vehicles must slow down because of backups from the construction zone. In other words, the counts are far enough upstream of the work zone and at a location where none of the drivers must reduce their speeds. You must use good judgement in selecting the count location. Remember, the backup may not take place until after you start counting. So be sure you leave enough distance for a certain amount of backup to occur.

You will separate your counts into two groups: Cars (C) and Trucks (T). The following vehicles will be counted as Cars and recorded in the "C" column on Form B1: cars, vans, pickup trucks, and small trucks with 2 axles. Trucks with 3 or more axles and buses will be counted as Trucks and recorded in the "T" column.

Data are recorded on Form B1. Record the counts every 15 minutes. You should <u>not</u> reset the counters until the end of the 2-hour study. Simply cummulate the counts. The counts can be made and recorded by one person. Make sure you make a note on Form B1 during each 15-minute period that the traffic queue comes near your count station. Continue the counts until 9:00 a.m..

<u>Entrance and Exit Ramps</u>

At construction sites where entrance and exit ramps are located between count stations 1+2 (or 3+4) and 5 or 6, additional persons must make traffic counts at the entrance and/or exit ramps using Form B1-Ramps. Follow the instructions given in paragraphs 3 and 4 in the above section on A.M. Peak Study 1, except use Form B1-Ramp.

A.M. PEAK STUDY 2

Another person uses Form C to record (1) the length of queue (backup) measured from the beginning of the lane closure (barricade or cone taper), and (2) the travel time through the construction zone. You will use the car odometer (mileage indicator) to determine the distance of the queue, and your watch or a stop watch to determine the travel times. Starting at 7:00 a.m. simply drive your car in traffic in the heavy traffic Direction (See Form B1), on one of the lanes. When you arrive at the tail end of the queue, note and record (1) the odometer reading to the nearest one-tenth of a mile and (2) the time on your watch to the nearest second. (If you are using a stop watch turn the watch on at this point.) If there is no backup make a note a note on the Form. You must have a record for every run.

Stay in the lane and move in traffic. When you reach the beginning of the lane closure (taper), record (1) the odometer reading and (2) the time on your watch or stop watch.

Drive through the construction zone. When you arrive at the end of the lane closure record (1) the odometer reading and (2) the time.

Then turn around and travel in the opposite Direction. After you pass the construction area and the backup in the heavy traffic Direction, turn around and make another run in the heavy traffic Direction in a different lane. Repeat the data collection procedure. However, each time you make a run, use a different lane. That is drive lane 1 the first time, lane 2 the second time, lane 1 the third, etc.

Continue this study until 9:00 a.m.

A.M. PEAK STUDY 3

Count the vehicles traveling past Station 5 or Station 6 (depending upon which lane is closed) during the 2-hour study period. Use Form B1 to record the counts every 15 minutes. Be sure you group the vehicles into Cars (C) or Trucks (T) just like you did in A.M. Peak Study 1. Position yourself so that you can see whether vehicles are backing up because of the lane closure. Make a note each 15-minute period to indicate whether vehicles were backed up throughout the 15-minute period. There is a special column on Form B1 to record information about whether queues are present.

OFF-PEAK STUDY 1

Make the necessary measurements to complete Form A. It will take two persons to make the measurements. Some distances such as the width of a lane will be measured in feet and inches with a tape measure; other distances such as the length of the lane closure will be measured to the nearest one-tenth of a mile with the odometer of your car.

OFF-PEAK STUDY 2

Use Form D to sample the vehicle occupancy--the number of people in the vehicles traveling on the highway. Collect data in the heavy traffic Direction until you record 100 vehicles. As a vehicle passes, count the number of people in the vehicle and place a check mark in the proper cell on Form C. You are going to be sampling, therefore you do not have to record every vehicle that passes. You might look at every third or fourth vehicle and record the number of people until you reach 100 vehicles. Remember to record in the proper cell. There is a place for cars, vans, trucks and buses.

After you record 100 vehicles, repeat the study in the opposite Direction. Again, record the vehicle occupancy for 100 vehicles.

P.M. PEAK STUDY 1

Starting at 4:00 p.m.,collect two hours of traffic counts on the highway in the direction of the peak traffic flow. This will be at either Location 1+2 (See Form B1) or Location 3+4 depending upon which direction the peak traffic is going.

The counts must be made far enough before (upstream) the construction zone so that none of the vehicles must slow down because of backups from the construction zone. In other words, the counts are far enough upstream of the work zone and at a location where none of the drivers must reduce their speeds. You must use good judgement in selecting the count location. Remember, the backup may not take place until after you start counting. So be sure you leave enough distance for a certain amount of backup to occur.

Just like you did for A.M. Peak Study 1, you will separate your counts into two groups: Cars (C) and Trucks (T). The following vehicles will be counted as Cars and recorded in the "C" column on Form B1: cars, vans, pickup trucks, and small trucks with 2 axles. Trucks with 3 or more axles and buses will be counted as Trucks and recorded in the "T" column.

Data are recorded on Form B1. Record the counts every 15 minutes. You should <u>not</u> reset the counters until the end of the 2-hour study. Simply cummulate the counts. The counts can be made and recorded by one person. Make sure you make a note on Form B1 during each 15-minute period that the traffic queue comes near your count station. Continue the counts until 6:00 p.m.

Entrance and Exit Ramps

At construction sites where entrance and exit ramps are located between count stations 1+2 (or 3+4) and 5 or 6, additional persons must make traffic counts at the entrance and/or exit ramps using Form B1-Ramps. Follow the instructions given in paragraphs 3 and 4 in the above section on P.M. Peak Study 1, except use Form B1-Ramp.

P.M. PEAK STUDY 2

Another person uses Form C to record (1) the length of queue (backup) measured from the beginning of the lane closure (barricade or cone taper), and (2) the travel time through the construction zone. You will use the car odometer (mileage indicator) to determine the distance of the queue, and your watch or a stop watch to determine the travel times. Starting at 4:00 p.m. simply drive your car in traffic in the heavy traffic Direction (See Form B1) on one of the lanes. When you arrive at the tail end of the queue, note and record (1) the odometer reading to the nearest one-tenth of a mile and (2) the time on your watch. (If you are using a stop watch turn the watch on at this point.) If there is no backup make a note on the Form. You must have a record for every run.

Stay in the lane and move in traffic. When you reach the beginning of the lane closure (taper), record (1) the odometer reading and (2) the time on your watch or stop watch.

Drive through the construction zone. When you arrive at the end of the lane closure record (1) the odometer reading and (2) the time.

Then turn around and travel in the opposite Direction. After you pass the construction area and the backup in the heavy traffic Direction, turn around and make another run in the heavy traffic Direction in a different lane. Repeat the data collection procedure. However, each time you make a run, use a different lane. That is drive lane 1 the first time, lane 2 the second time, lane 1 the third. etc. Continue this study until 6:00 p.m.

P.M. PEAK STUDY 3

Count the vehicles traveling past Station 5 or Station 6 (depending upon which lane is closed) during the 2-hour study period. Use Form B1 to record the counts every 15 minutes. Be sure you group the vehicles into Cars (C) or Trucks (T) just like you did in A.M. Peak Study 1. Position yourself so that you can see whether vehicles are backing up because of the lane closure. Make a note each 15-minute period to indicate whether vehicles were backed up throughout the 15-minute period. There is a special column on Form B1 to record information about whether queues are present.

Form A--Site characteristics.

1. Site #:____ Date__________
2. State:________________
3. Location (City, Highway):________________________
   ____feet [North South East West] (Circle One) Mile Marker No.________
4. Type of traffic control (Single Lane Closure or Crossover):____________

5a. Length of single lane closure (Beginning of taper to end of lane closure):_____miles (Direction 1)

5b. Length of single lane closure (Beginning of taper to end of lane closure):_____miles (Direction 2 for closures in both directions)

5c. Length of crossover (Beginning of taper on the side closed for construction to the location at the end of the crossover where the two lanes begin again in the same direction):_____miles

6. Width of roadway at Station 5* including shoulder:_____feet
7. Width of roadway at Station 6* including shoulder:_____feet
8. Width of roadway at Station 7* including shoulder:_____feet (for closures in both directions)
9. Width of roadway at Station 8* including shoulder:_____feet (for closures in both directions)
10. Width of normal highway lanes:_____feet
11. Width of shoulder next to lane 1*:_____feet
12. Width of shoulder next to lane 2*:_____feet
13. Width of median:_____feet
14. Width of shoulder next to lane 3*:_____feet
15. Width of shoulder next to lane 4*:_____feet
16. What type of traffic control device (concrete barriers, cones, barrels, etc) is being used to separate the workers from traffic at the location where there is only one lane? ____________________________
17. What type of traffic control device (concrete barriers, cones, barrels, etc) is being used to separate the two lanes of traffic at the location where there are two lanes on one side? ________________
18. In addition to the above, draw a sketch of the location of all traffic control devices, ramps, beginning and end of lane closures or crossovers, etc.

* See Forms B1 & B2

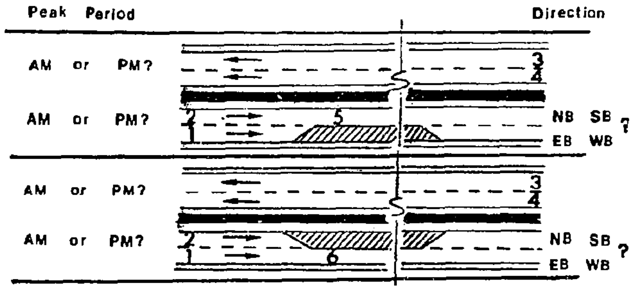
Form B1--Traffic counts and queues (SLC in one direction only).

FORM B1

Date__________ Sites__________

State__________

Location__________ Recorder__________



TIME		COUNTER READING								
Time Begin	Time End	1 + 2		5		6		3 + 4		Queue ? Y or N
		C	T	C	T	C	T	C	T	

Sheet__of 2

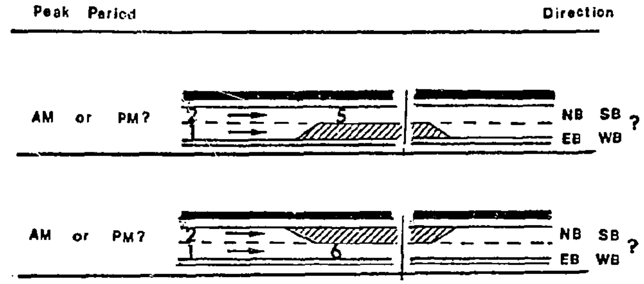
Form B1-OP1--Traffic counts and queues (SLC in both directions/direction 1).

FORM B1-OP1

Date__________ Sites__________

State__________

Location__________ Recorder__________



TIME		COUNTER READING								
Time Begin	Time End	1 + 2		5		6				Queue ? Y or N
		C	T	C	T	C	T			

Sheet__of 2

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Form B1-OP2--Traffic counts and queues (SLC in both directions/direction 2).

FORM B1-OP2

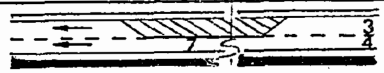
Date____________ Site#__________

Location__________ State__________

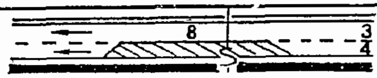
Recorder__________

Peak Period — Direction

AM or PM?



AM or PM?



TIME		COUNTER READING								
Time Begin	Time End			7		8		3 + 4		Queue ? Y or N
				C	T	C	T	C	T	

Sheet__of 2

Form B2--Traffic counts and queues (TLTWO).

FORM B2

Date____________ Site#__________

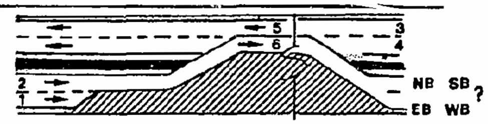
Location__________ State__________

Recorder__________

Peak Period — Direction

AM or PM?

AM or PM?



TIME		COUNTER READING								
Time Begin	Time End	1 + 2		5		6		3 + 4		Queue ? Y or N (Time)
		C	T	C	T	C	T	C	T	

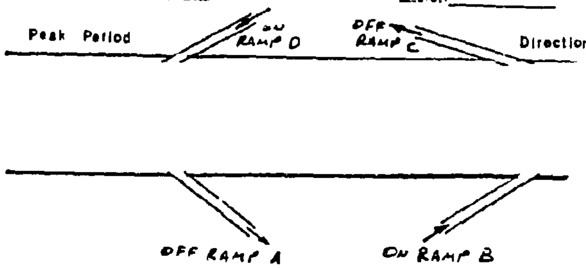
Sheet__of 2

Form B2-Ramps--Traffic counts on entrance and exit ramps (SLC and TLTWO).

Date__________ FORM B2 RAMPS Site__________

Location__________ State__________

Recorder__________



TIME		COUNTER READING								
Time Begin	Time End	OFF RAMP A		ON RAMP B		OFF RAMP C		ON RAMP D		Queue ? Y or N (Time)
		C	T	C	T	C	T	C	T	

Sheet__of 2

Form C--Travel time and queue lengths (SLC and TLTWO).

Date__________ FORM C Site # __________

Location__________ State__________

Recorder__________

Direction
NB SB
EB WB

Time	Lane	End of Queue		Beginning of Lane Closure		End of Closure
		Odometer	Time	Odometer	Time	Time

Form D--Vehicle occupancy (SLC and TLTWO).

FORM D

Vehicle Occupancy

Site # ________

Location ________

Recorders ________

State ________

Date ________, Time of Day ________

NB SB EB WB

Type of Vehicles	Vehicles by Number of Occupants													
	1 Person		2 Persons		3 Persons		4 Persons		5 Persons		6 Persons		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Cars														
Vans														
Trucks														
Buses														
TOTAL														100%

FIELD DATA COLLECTION INSTRUCTIONS
WEEKDAY PEAK PERIODS
TWO-LANE, TWO-WAY OPERATIONS

Period of Time

Field data collection can be completed during a 2-day period for Two- Lane, Two-Way Operation traffic control plans when two persons collect data, or during a 1-day period when three or more persons collect data. Note: One additional person must be used for every entrance (on) or exit (off) ramp where traffic counts must be made.

Two-Person Crew

Data must be collected during the a.m. peak, off-peak and p.m. peak periods. Whether you start during the a.m. peak or p.m. peak will be determined by your travel schedule. It is anticipated that studies will be conducted at two construction sites in one week. This requires that the studies begin at the first site during the a.m. peak period on Monday. The studies at the second site will begin during the p.m. peak on Wednesday.

During the a.m. and p.m. peak periods, data will be collected for 2 consecutive hours. The a.m. peak period is from 7:00 a.m. to 9:00 a.m. The p.m. peak period is from 4:00 p.m. to 6:00 p.m. Off-peak hours for data collection are between 9:00 a.m. and 3:00 p.m.

Schedule A	Schedule B
1. a.m. peak (day 1)	1. p.m. peak (day 1)
2. off-peak (day 1)	2. a.m. peak (day 2)
3. p.m. peak (day 1)	3. off-peak (day 2)
4. a.m. peak (day 2)	4. p.m. peak (day 2)
5. p.m. peak (day 2)	5. a.m. peak (day 3)

Page 2 identifies the specific studies and the schedule of the studies that must be conducted.

TWO-PERSON CREW

(Additional persons may be needed to count traffic on the ramps)

Two-Lane, Two-Way Operation Studies Beginning During the A.M. Peak

1. Day 1: Conduct A.M. Study 1
2. Day 1: Conduct A.M. Study 2
3. Day 1: Conduct Off-Peak Study 1
4. Day 1: Conduct Off-Peak Study 2
5. Day 1: Conduct P.M. Study 1
6. Day 1: Conduct P.M. Study 2

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7. Day 2: Conduct A.M. Study 3
8. Day 2: Conduct A.M. Study 2
9. Day 2: Conduct P.M. Study 3
10. Day 2: Conduct P.M. Study 2

Two-Lane, Two-Way Operation Studies Beginning During The P.M. Peak

1. Day 1: Conduct P.M. Study 1
2. Day 1: Conduct P.M. Study 2

---

3. Day 2: Conduct A.M. Study 1
4. Day 2: Conduct A.M. Study 2
5. Day 2: Conduct Off-Peak Study 1
6. Day 2: Conduct Off-Peak Study 2
7. Day 2: Conduct P.M. Study 3
8. Day 2: Conduct P.M. Study 2

---

9. Day 3: Conduct A.M. Study 3
10. Day 3: Conduct A.M. Study 2

Three- or More Person Crew

Data must be collected during the a.m. peak, off-peak and p.m. peak periods. It is preferred that data collection start during the a.m. peak period so that data can be collected at a site during one day, eliminating the need to spend a night in a motel or making an extra trip to the work site. However, if necessary, data collection can begin during the off-peak or p.m. peak period. The following schedules apply:

(Preferred)

Schedule A	Schedule B	Schedule C
1. a.m. peak (day 1)	1. off-peak (day 1)	1. p.m. peak (day 1)
2. off-peak (day 1)	2. p.m. peak (day 1)	2. a.m. peak (day 2)
3. p.m. peak (day 1)	3. a.m. peak (day 2)	3. off-peak (day 2)

During the a.m. and p.m. peak periods, data should be collected for 2 consecutive hours. The a.m. peak period is from 7:00 a.m. to 9:00 a.m. The p.m. peak period is from 4:00 p.m. to 6:00 p.m. Off-peak hours for data collection are between 9:00 a.m. and 3:00 p.m.

Page 4 identifies the specific studies and the schedule of the studies that must be conducted.

THREE- OR MORE PERSON CREW

(Additional persons may be needed to count traffic on the ramps)

Two-Lane, Two-Way Operation Studies BeginniningDuring TheA.M. Peak (Preferred)

1. Day 1: Conduct A.M. Study 1
2. Day 1: Conduct A.M. Study 2
3. Day 1: Conduct A.M. Study 3
4. Day 1: Conduct Off-Peak Study 1
5. Day 1: Conduct Off-Peak Study 2
6. Day 1: Conduct P.M. Study 1
7. Day 1: Conduct P.M. Study 2
8. Day 1: Conduct P.M. Study 3

Two-Lane, Two-Way Operation Studies Beginning During The Off-Peak (Optional)

1. Day 1: Conduct Off-Peak Study 1
2. Day 1: Conduct Off-Peak Study 2
3. Day 1: Conduct P.M. Study 1
4. Day 1: Conduct P.M. Study 2
5. Day 1: Conduct P.M. Study 3

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6. Day 2: Conduct A.M. Study 1
7. Day 2: Conduct A.M. Study 2
8. Day 2: Conduct A.M. Study 3

Two-Lane, Two-Way Operation Studies Beginning During The P.M. Peak (Optional)

1. Day 1: Conduct P.M. Study 1
2. Day 1: Conduct P.M. Study 2
3. Day 1: Conduct P.M. Study 3

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4. Day 2: Conduct A.M. Study 1
5. Day 2: Conduct A.M. Study 2
6. Day 2: Conduct A.M. Study 3
7. Day 2: Conduct Off-Peak Study 1
8. Day 2: Conduct Off-Peak Study 2

TWO-LANE, TWO-WAY OPERATION STUDY DETAILS

A.M. PEAK STUDY 1

Starting at 7:00 a.m., collect two hours of traffic counts on the highway in the direction of the peak traffic flow. This will be at either Location 1+2 or Location 3+4 in the Northbound, Southbound, Eastbound, or Westbound heavy traffic Direction, whichever applies (See Form B2).

The counts must be made far enough before (upstream) the construction zone to assure that none of the vehicles must slow down because of backups from the construction zone. In other words, the counts are far enough upstream of the work zone and at a location where none of the drivers must reduce their speeds. You must use good judgement in selecting the count location. Remember, the backup may not take place until after you start counting. So be sure you leave enough distance for a certain amount of backup to occur.

You will separate your counts into two groups: Cars (C) and Trucks (T). The following vehicles will be counted as Cars and recorded in the "C" column on Form B2: cars, vans, pickup trucks, and small trucks with 2 axles. Trucks with 3 or more axles and buses will be counted as Trucks and recorded in the "T" column.

Data are recorded on Form B2. Record the counts every 15 minutes. You should not reset the counters until the end of the 2-hour study. Simply cummulate the counts. The counts can be made and recorded by one person. Make sure you make a note on Form B2 during each 15-minute period that the traffic queue comes near your count station. Continue the counts until 9:00 a.m.

Entrance and Exit Ramps

At construction sites where entrance and exit ramps are located between count stations 1+2 (or 3+4) and 5 or 6, additional persons must make traffic counts at the entrance and/or exit ramps using Form B2-Ramps. Follow the instructions given in paragraphs 3 and 4 in the above section on A.M. Peak Study 1, except use Form B2-Ramp.

A.M. PEAK STUDY 2

The second person uses Form C to record (1) the length of queue (backup) measured from the beginning of the lane closure (barricade or cone taper), and (2) the travel time through the construction zone. You will use the car odometer (mileage indicator) to determine the distance of the queue, and your watch or a stop watch to determine the travel times. Starting at 7:00 a.m. simply drive your car in traffic in the heavy traffic Direction (See Form B2) on one of the lanes. When you arrive at the tail end of the queue, note and record (1) the odometer reading to the nearest one-tenth of a mile and (2) the time on your watch to the nearest second. (If you are using a stop watch turn the watch on at this point.) If there is no backup make a note a note on the Form. You must have a record for every run.

Stay in the lane and move in traffic. When you reach the beginning of the lane closure (taper), record (1) the odometer reading and (2) the time on your watch or stop watch.

Drive through the construction zone. When you arrive at the end of the lane closure record (1) the odometer reading and (2) the time.

Then turn around and travel in the opposite Direction. Collect and record the same type data in the opposite Direction as you did in the heavy traffic Direction.

After you pass through the lane closure in the opposite Direction, turn around and make another run in the heavy traffic Direction in a different lane. Repeat the data collection procedure. However, each time you make a run, use a different lane. That is drive lane 1 the first time, lane 2 the second time, lane 1 the third, etc.

Continue this study until 9:00 a.m.

A.M. PEAK STUDY 3

Count the vehicles traveling past Station 5 or Station 6 (depending upon which lane is closed) during the 2-hour study period. Use Form B2 to record the counts every 15 minutes. Be sure you group the vehicles into Cars (C) or Trucks (T) just like you did in A.M. Peak Study 1. Position yourself so that you can see whether vehicles are backing up because of the lane closure. Make a note each 15-minute period to indicate whether vehicles were backed up throughout the 15-minute period. There is a special column on Form B2 to record information about whether queues are present.

OFF-PEAK STUDY 1

Make the necessary measurements to complete Form A. It will take two persons to make the measurements. Some distances such as the width of a lane will be measured in feet and inches with a tape

measure; other distances such as the length of the lane closure will be measured to the nearest one-tenth of a mile with the odometer of your car.

OFF-PEAK STUDY 2

Use Form D to sample the vehicle occupancy--the number of people in the vehicles traveling on the highway. Collect data in the heavy traffic Direction until you record 100 vehicles. As a vehicle passes, count the number of people in the vehicle and place a check mark in the proper cell on Form C. You are going to be sampling, therefore you do not have to record every vehicle that passes. You might look at every third or fourth vehicle and record the number of people until you reach 100 vehicles. Remember to record in the proper cell. There is a place for cars, vans, trucks and buses.

After you record 100 vehicles, repeat the study in the opposite Direction. Again, record the vehicle occupancy for 100 vehicles.

P.M. PEAK STUDY 1

Starting at 4:00 p.m.,collect two hours of traffic counts on the highway in the direction of the peak traffic flow. This will be at either Location 1+2 (See Form B2) or Location 3+4 depending upon which direction the peak traffic is going.

The counts must be made far enough before (upstream) the construction zone so that none of the vehicles must slow down because of backups from the construction zone. In other words, the counts are far enough upstream of the work zone and at a location where none of the drivers must reduce their speeds. You must use good judgement in selecting the count location. Remember, the backup may not take place until after you start counting. So be sure you leave enough distance for a certain amount of backup to occur.

Just like you did for A.M. Peak Study 1, you will separate your counts into two groups: Cars (C) and Trucks (T). The following vehicles will be counted as Cars and recorded in the "C" column on Form B2: cars, vans, pickup trucks, and small trucks with 2 axles. Trucks with 3 or more axles and buses will be counted as Trucks and recorded in the "T" column.

Data are recorded on Form B2. Record the counts every 15 minutes. You should <u>not</u> reset the counters until the end of the 2-hour study. Simply cummulate the counts. The counts can be made and recorded by one person. Make sure you make a note on Form B2 during each 15-minute period that the traffic queue comes near your count station. Continue the counts until 6:00 p.m.

Entrance and Exit Ramps

At construction sites where entrance and exit ramps are located between count stations 1+2 (or 3+4) and 5 or 6, additional persons must make traffic counts at the entrance and/or exit ramps using Form B2-Ramps. Follow the instructions given in paragraphs 3 and 4 in the above section on A.M. Peak Study 1, except use Form B2-Ramp.

P.M. PEAK STUDY 2

The second person uses Form C to record (1) the length of queue (backup) measured from the beginning of the lane closure (barricade or cone taper), and (2) the travel time through the construction zone. You will use the car odometer (mileage indicator) to determine the distance of the queue, and your watch or a stop watch to determine the travel times. Starting at 4:00 p.m. simply drive your car in traffic in the heavy traffic Direction (See Form B2) on one of the lanes. When you arrive at the tail end of the queue, note and record (1) the odometer reading to the nearest one-tenth of a mile and (2) the time on your watch. (If you are using a stop watch turn the watch on at this point.) If there is no backup make a note on the Form. You must have a record for every run.

Stay in the lane and move in traffic. When you reach the beginning of the lane closure (taper), record (1) the odometer reading and (2) the time on your watch or stop watch.

Drive through the construction zone. When you arrive at the end of the lane closure record (1) the odometer reading and (2) the time.

Then turn around and travel in the opposite Direction. Collect and record the same data in the opposite Direction as you did for the heavy traffic Direction.

After you pass the construction area and the backup in the heavy traffic Direction, turn around and make another run in the heavy traffic Direction in a different lane. Repeat the data collection procedure. However, each time you make a run, use a different lane. That is drive lane 1 the first time, lane 2 the second time, lane 1 the third, etc. Continue this study until 6:00 p.m.

P.M. PEAK STUDY 3

Count the vehicles traveling past Station 5 or Station 6 (depending upon which lane is closed) during the 2-hour study

period. Use Form B2 to record the counts every 15 minutes. Be sure you group the vehicles into Cars (C) or Trucks (T) just like you did in A.M. Peak Study 1. Position yourself so that you can see whether vehicles are backing up because of the lane closure. Make a note each 15-minute period to indicate whether vehicles were backed up throughout the 15-minute period. There is a special column on Form B2 to record information about whether queues are present.

FIELD DATA COLLECTION INSTRUCTIONS
WEEKDAY OFF-PEAK
SINGLE-LANE CLOSURES

Offpeak Single-Lane Closure Studies

There will be some study construction sites (for example, pavement overlay projects) where because of the type of construction and the extremely high traffic volumes during the morning and afternoon peak periods, traffic lanes are closed only during off-peak periods. Therefore data will be collected only during the off-peak periods on weekdays. A minimum of three persons are required to conduct the off-peak studies. Additional persons are required if traffic counts must be made at entrance (on) and exit (off) ramps.

Period of Time

Field data will be collected on weekdays after the morning peak period but before the afternoon peak period begins. The starting time may be different at each study site; however, it is expected that the study will be conducted somewhere between 9 a.m. and 4 p.m. Dr. Dudek will determine the starting time for each weekday study. You are to contact him for instructions.

Lane Closure In One Direction Only

1. Travel To Study Site
2. Conduct Weekday Off-Peak Study 1
3. Conduct Weekday Off-Peak Study 2
4. Conduct Weekday Off-Peak Study 3
5. Conduct Weekday Off-Peak Study 4
6. Conduct Weekday Off-Peak Study 5
7. Return Home

Lane Closures In Both Directions

1. Travel To Study Site
2. Conduct Weekday Off-Peak Study 6
3. Conduct Weekday Off-Peak Study 7
4. Conduct Weekday Off-Peak Study 8
5. Conduct Weekday Off-Peak Study 9
6. Conduct Weekday Off-Peak Study 10
7. Conduct Weekday Off-Peak Study 11
8. Conduct Weekday Off-Peak Study 12
9. Conduct Weekday Off-Peak Study 13
10. Return Home

OFF-PEAK SINGLE-LANE CLOSURE STUDY DETAILS

LANE CLOSURE IN ONE DIRECTION ONLY

WEEKDAY OFF-PEAK STUDY 1

Starting at a time specified by Dr. Conrad L. Dudek, collect two or three hours (as specified by Dr. Dudek) of traffic counts on the highway in the closed lane direction. This will be at Location 1+2 in the Northbound, Southbound, Eastbound, or Westbound lane closure Direction, whichever applies (See Form B1).

The counts must be made far enough before (upstream) the construction zone to assure that none of the vehicles must slow down because of backups from the construction zone. In other words, the counts are far enough upstream of the work zone and at a location where none of the drivers must reduce their speeds. You must use good judgement in selecting the count location. Remember, the backup may not take place until after you start counting. So be sure you leave enough distance for a certain amount of backup to occur.

You will separate your counts into two groups: Cars (C) and Trucks (T). The following vehicles will be counted as Cars and recorded in the "C" column on Form B1: cars, vans, pickup trucks, and small trucks with 2 axles. Trucks with 3 or more axles and buses will be counted as Trucks and recorded in the "T" column.

Data are recorded on Form B1. Record the counts every 15 minutes. You should not reset the counters until the end of the 2- or 3-hour study. Simply cummulate the counts. The counts can be made and recorded by one person. Make sure you make a note on Form B1 during each 15-minute period that the traffic queue comes near your count station. Continue the counts until the 2- or 3-hour study period has ended.

Entrance and Exit Ramps

At construction sites where entrance and exit ramps are located between count stations 1+2 (or 3+4) and 5 or 6, additional persons must make traffic counts at the entrance and/or exit ramps using Form B1-Ramps. Follow the instructions given in paragraphs 3 and 4 in the above section on Weekday Off- Peak Study 1, except use Form B1-Ramp.

WEEKDAY OFF-PEAK STUDY 2

The second person uses Form C to record (1) the length of queue (backup) measured from the beginning of the lane closure (barricade or cone taper), and (2) the travel time through the construction zone. You will use the car odometer (mileage indicator) to determine the distance of the queue, and your watch or a stop watch to determine the travel times. Starting at the time specified by Dr. Dudek, simply drive your car in traffic in the closed lane Direction (See Form B1), on one of the lanes. When you arrive at the tail end of the queue, note and record (1) the odometer reading to the nearest one- tenth of a mile and (2) the time on your watch to the nearest second. (If you are using a stop watch turn the watch on at this point.) If there is no backup make a note on the Form. You must have a record for every run.

Stay in the lane and move in traffic. When you reach the beginning of the lane closure (taper), record (1) the odometer reading and (2) the time on your watch or stop watch.

Drive through the construction zone. When you arrive at the end of the lane closure, record (1) the odometer reading and (2) the time.

Then turn around and travel in the opposite Direction. After you pass the construction area and the backup in the closed lane Direction, turn around and make another run in the closed lane Direction in a different lane. Repeat the data collection procedure. However, each time you make a run, use a different lane. That is drive lane 1 the first time, lane 2 the second time, lane 1 the third, etc.

Continue this study until the end of the 2- or 3-hour period.

WEEKDAY OFF-PEAK STUDY 3

The third person will count the vehicles traveling past Station 5 or Station 6 (depending upon which lane is closed) during the 2- or 3-hour study period. Use **Form B1** to record the counts every 15 minutes. Be sure you group the vehicles into Cars (C) or Trucks (T) just like Weekday Off-Peak Study 1. Position yourself so that you can see whether vehicles are backing up because of the lane closure. Make a note each 15-minute period to indicate whether vehicles were backed up throughout the 15-minute period. There is a special column on Form B1 to record information about the queues.

WEEKDAY OFF-PEAK STUDY 4

Starting at a time specified by Dr. Dudek, make the necessary measurements to complete Form A. It will take two persons to make the measurements. Some distances such as the width of a lane will be measured in feet and inches with a tape measure; other distances such as the length of the lane closure will be measured to the nearest one-tenth of a mile with the odometer of your car.

WEEKDAY OFF-PEAK STUDY 5

Starting at a time specified by Dr. Dudek, one person can sample the vehicle occupancy--the number of people in the vehicles traveling on the highway using Form D. Collect data in the closed lane Direction until you record 100 vehicles. As a vehicle passes, count the number of people in the vehicle and place a check mark in the proper cell on Form C. You are going to be sampling, therefore you do not have to record every vehicle that passes. You might look at every third or fourth vehicle and record the number of people until you reach 100 vehicles. Remember to record in the proper cell. There is a place for cars, vans, trucks and buses.

After you record 100 vehicles, conduct the same study in the opposite Direction. Again, record the vehicle occupancy for 100 vehicles.

<u>LANE-CLOSURES IN BOTH DIRECTIONS</u>

WEEKDAY OFF-PEAK STUDY 6

Starting at a time specified by Dr. Conrad L. Dudek, collect two or three hours (as specified by Dr. Dudek) of traffic counts on the highway in one direction (Let's refer to it as Direction 1. This will be at Location 1+2 in the Northbound, Southbound, Eastbound, or Westbound lane closure Direction, whichever applies. You will use Form B1-OP1.

The counts must be made far enough before (upstream) the construction zone to assure that none of the vehicles must slow down because of backups from the construction zone. In other words, the counts are far enough upstream of the work zone and at a location where none of the drivers must reduce their speeds. You must use good judgement in selecting the count location. Remember, the backup may not take place until after you start counting. So be sure you leave enough distance for a certain amount of backup to occur.

You will separate your counts into two groups: Cars (C) and Trucks (T). The following vehicles will be counted as Cars and recorded in the "C" column on Form B1-OP1: cars, vans, pickup trucks, and small trucks with 2 axles. Trucks with 3 or more axles and buses will be counted as Trucks and recorded in the "T" column.

Data are recorded on Form B1-OP1. Record the counts every 15 minutes. You should <u>not</u> reset the counters until the end of the 2-hour study. Simply cummulate the counts. The counts can be made and recorded by one person. Make sure you make a note on Form B1 during each 15-minute period that the traffic queue comes near your count station.

Continue the counts until the end of the 2- or 3-hour period.

Entrance and Exit Ramps

At construction sites where entrance and exit ramps are located between count stations 1+2 and 5 or 6, additional persons must make traffic counts at the entrance and/or exit ramps using Form B1-Ramp. Follow the instructions given in paragraphs 3 and 4 in the above section on Weekday Off-Peak Study 6, except use Form B1-Ramp.

WEEKDAY OFF-PEAK STUDY 7

The second person uses Form C to record (1) the length of queue (backup) measured from the beginning of the lane closure (barricade or cone taper), and (2) the travel time through the construction zone. You will use the car odometer (mileage indicator) to determine the distance of the queue, and your watch or a stop watch to determine the travel times. Starting at a time specified by Dr. Dudek, simply drive your car in traffic in one direction (let's call it Direction 1) on one of the lanes. When you arrive at the tail end of the queue, note and record (1) the odometer reading to the nearest one- tenth of a mile and (2) the time on your watch to the nearest second. (If you are using a stop watch turn the watch on at this point.) If there is no backup make a note on the Form. You must have a record for every run.

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Stay in the lane and move in traffic. When you reach the beginning of the lane closure (taper), record (1) the odometer reading and (2) the time on your watch or stop watch.

Drive through the construction zone. When you arrive at the end of the lane closure, record (1) the odometer reading and (2) the time.

Then turn around and travel in the opposite Direction. Collect and record the same type data in the opposite Direction as you did in Direction 1. Drive your car in traffic in the opposite Direction (See Form B1-OP2) on one of the lanes. When you arrive at the tail end of the queue, note and record (1) the odometer reading to the nearest one-tenth of a mile and (2) the time on your watch to the nearest second. (If you are using a stop watch turn the watch on at this point.) If there is no backup make a note on the Form. You must have a record for every run.

Stay in the lane and move in traffic. When you reach the beginning of the lane closure (taper), record (1) the odometer reading and (2) the time on your watch or stop watch.

Drive through the construction zone. When you arrive at the

end of the lane closure record (1) the odometer reading and (2) the time.

After you pass through the lane closure in the opposite Direction, turn around and make another run in Direction 1 in a different lane. Repeat the data collection procedure. However, each time you make a run, use a different lane. That is drive lane 1 the first time, lane 2 the second time, lane 1 the third, etc.

Continue this study until the 2- or 3-hour period ends.

WEEKDAY OFF-PEAK STUDY 8

The third person counts the vehicles traveling past Station 5 or Station 6 (depending upon which lane is closed) during the 2- or 3-hour study period. Use Form B1-OP1 to record the counts every 15 minutes. Be sure you group the vehicles into Cars (C) or Trucks (T) just like in Study 6. Position yourself so that you can see whether vehicles are backing up because of the lane closure. Make a note each 15-minute period to indicate whether vehicles were backed up throughout the 15-minute period. There is a special column on Form B1 to record information about whether queues are present.

WEEKDAY OFF-PEAK STUDY 9

Make the necessary measurements to complete Form A. It will take two persons to make the measurements. Some distances such as the width of a lane will be measured in feet and inches with a tape measure; other distances such as the length of the lane closure will be measured to the nearest one-tenth of a mile with the odometer of your car.

WEEKDAY OFF-PEAK STUDY 10

Use Form D to sample the vehicle occupancy--the number of people in the vehicles traveling on the highway. Collect data in Direction 1 until you record 100 vehicles. As a vehicle passes, count the number of people in the vehicle and place a check mark in the proper cell on Form C. You are going to be sampling, therefore you do not have to record every vehicle that passes. You might look at every third or fourth vehicle and record the number of people until you reach 100 vehicles. Remember to record in the proper cell. There is a place for cars, vans, trucks and buses.

After you record 100 vehicles, repeat the study in the opposite Direction . Again, record the vehicle occupancy for 100 vehicles.

WEEKDAY OFF-PEAK STUDY 11

Starting at a time specified by Dr. Conrad L. Dudek, collect two or three hours (as specified by Dr. Dudek) of traffic counts on the highway in the opposite Direction. This will be at Location 3+4 in the Northbound, Southbound, Eastbound, or Westbound lane closure Direction, whichever applies. You will use Form B1-OP2.

The counts must be made far enough before (upstream) the construction zone to assure that none of the vehicles must slow down because of backups from the construction zone. In other words, the counts are far enough upstream of the work zone and at a location where none of the drivers must reduce their speeds. You must use good judgement in selecting the count location. Remember, the backup may not take place until after you start counting. So be sure you leave enough distance for a certain amount of backup to occur.

You will separate your counts into two groups: Cars (C) and Trucks (T). The following vehicles will be counted as Cars and recorded in the "C" column on Form B1-OP2: cars, vans, pickup trucks, and small trucks with 2 axles. Trucks with 3 or more axles and buses will be counted as Trucks and recorded in the "T" column.

Data are recorded on Form B1-OP2. Record the counts every 15 minutes. You should <u>not</u> reset the counters until the end of the 2-hour study. Simply cummulate the counts. The counts can be made and recorded by one person. Make sure you make a note on Form B1 during each 15-minute period that the traffic queue comes near your count station.

Continue the counts untilthe end of the 2- or 3-hour period.

<u>Entrance and Exit Ramps</u>

At construction sites where entrance and exit ramps are located between count stations 3+4 and 7 or 8, additional persons must make traffic counts at the entrance and/or exit ramps using Form B1-Ramp. Follow the instructions given in paragraphs 3 and 4 in the above section on Weekday Off-Peak Study 11, except use Form B1-Ramp.

WEEKDAY OFF-PEAK STUDY 12

The second person uses Form C to record (1) the length of queue (backup) measured from the beginning of the lane closure (barricade or cone taper), and (2) the travel time through the construction zone. You will use the car odometer (mileage indicator) to determine the distance of the queue, and your watch or a stop watch to determine the travel times. Starting at a time specified by Dr. Dudek, simply drive your car in traffic in the opposite Direction

on one of the lanes. When you arrive at the tail end of the queue, note and record (1) the odometer reading to the nearest one-tenth of a mile and (2) the time on your watch to the nearest second. (If you are using a stop watch turn the watch on at this point.) If there is no backup make a note on the Form. You must have a record for every run.

Stay in the lane and move in traffic. When you reach the beginning of the lane closure (taper), record (1) the odometer reading and (2) the time on your watch or stop watch.

Drive through the construction zone. When you arrive at the end of the lane closure, record (1) the odometer reading and (2) the time.

Then turn around and travel in Direction 1. Collect and record the same type data in the Direction 1 as you did in opposite Direction. Drive your car in traffic in the Direction 1 (See Form B1-OP1) on one of the lanes. When you arrive at the tail end of the queue, note and record (1) the odometer reading to the nearest one-tenth of a mile and (2) the time on your watch to the nearest second. (If you are using a stop watch turn the watch on at this point.) If there is no backup make a note a note on the Form. You must have a record for every run.

Stay in the lane and move in traffic. When you reach the beginning of the lane closure (taper), record (1) the odometer reading and (2) the time on your watch or stop watch.

Drive through the construction zone. When you arrive at the end of the lane closure record (1) the odometer reading and (2) the time.

After you pass through the lane closure in the Direction 1, turn around and make another run in the opposite Direction in a different lane. Repeat the data collection procedure. However, each time you make a run, use a different lane. That is drive lane 1 the first time, lane 2 the second time, lane 1 the third, etc.

Continue this study until the 2- or 3-hour period ends.

WEEKDAY OFF-PEAK STUDY 13

The third person counts the vehicles traveling past Station 7 or Station 8 (depending upon which lane is closed) during the 2- or 3-hour study period. Use Form B1-OP2 to record the counts every 15 minutes. Be sure you group the vehicles into Cars (C) or Trucks (T) just like in Study 11. Position yourself so that you can see whether vehicles are backing up because of the lane closure. Make a note each 15-minute period to indicate whether vehicles were backed up throughout the 15-minute period. There is a special column on Form B1 to record information whether queues are present.

FIELD DATA COLLECTION INSTRUCTIONS
WEEKEND
SINGLE LANE CLOSURES

Weekend Studies

There will be some study construction sites where the peak traffic periods occur on weekends--Friday afternoons and evenings with traffic moving away from large cities, and Sunday afternoons and evenings with traffic moving toward the large cities. Therefore data will be collected on Friday and Sunday at these sites, rather than during the week. Also, three people will be required to collect data on weekends. Note: One additional person must be used for every entrance (on) or exit (off) ramp where traffic counts must be made.

Period of Time

Field data will be collected on Friday afternoon and evening and on Sunday afternoon and evening for Single Lane Closure traffic control plans. The starting time may be different at each study site; however, it is expected that the study will be conducted somewhere between 3 p.m. and 8 p.m. Dr. Dudek will determine the starting time for each weekend study. You are to contact him for instructions.

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Lane Closure In The Outbound Direction

1. Travel To Study Site
2. Conduct Friday Off-Peak Study 1
3. Conduct Friday Off-Peak Study 2
4. Conduct Friday Peak Study 1
5. Conduct Friday Peak Study 2
6. Conduct Friday Peak Study 3
7. Return Home

Lane Closure In The Inbound Direction

1. Travel To Study Site
2. Conduct Sunday Off-Peak Study 1
3. Conduct Sunday Off-Peak Study 2
4. Conduct Sunday Peak Study 1
5. Conduct Sunday Peak Study 2
6. Conduct Sunday Peak Study 3
7. Return Home

WEEKEND
SINGLE LANE CLOSURE STUDY DETAILS

FRIDAY PEAK STUDY 1

Starting at a time specified by Dr. Conrad L. Dudek, collect two or three hours (as specified by Dr. Dudek) of traffic counts on the highway in the direction of the peak traffic flow. This will be at either Location 1+2 or Location 3+4 in the Northbound, Southbound, Eastbound, or Westbound heavy traffic Direction, whichever applies (See Form B1).

The counts must be made far enough before (upstream) the construction zone to assure that none of the vehicles must slow down because of backups from the construction zone. In other words, the counts are far enough upstream of the work zone and at a location where none of the drivers must reduce their speeds. You must use good judgement in selecting the count location. Remember, the backup may not take place until after you start counting. So be sure you leave enough distance for a certain amount of backup to occur.

You will separate your counts into two groups: Cars (C) and Trucks (T). The following vehicles will be counted as Cars and recorded in the "C" column on Form B1: cars, vans, pickup trucks, and small trucks with 2 axles. Trucks with 3 or more axles and buses will be counted as Trucks and recorded in the "T" column.

Data are recorded on Form B1. Record the counts every 15 minutes. You should not reset the counters until the end of the 2- or 3-hour study. Simply cummulate the counts. The counts can be made and recorded by one person. Make sure you make a note on Form B1 during each 15-minute period that the traffic queue comes near your count station. Continue the counts until the 2- or 3-hour study period has ended.

FRIDAY PEAK STUDY 2

The second person uses Form C to record (1) the length of queue (backup) measured from the beginning of the lane closure (barricade or cone taper), and (2) the travel time through the construction zone. You will use the car odometer (mileage indicator) to determine the distance of the queue, and your watch or a stop watch to determine the travel times. Starting at the time specified by Dr. Dudek, simply drive your car in traffic in the heavy traffic Direction (See Form B1), on one of the lanes. When you arrive at the tail end of the queue, note and record (1) the odometer reading to the nearest one- tenth of a mile and (2) the time on your watch to the nearest second. (If you are using a stop watch turn the watch on at this point.) If there is no backup make a note a note on the Form. You must have a record for every run.

Stay in the lane and move in traffic. When you reach the beginning of the lane closure (taper), record (1) the odometer reading and (2) the time on your watch or stop watch.

Drive through the construction zone. When you arrive at the end of the lane closure record (1) the odometer reading and (2) the time.

Then turn around and travel in the opposite Direction. After you pass the construction area and the backup in the heavy traffic Direction, turn around and make another run in the heavy traffic Direction in a different lane. Repeat the data collection procedure. However, each time you make a run, use a different lane. That is drive lane 1 the first time, lane 2 the second time, lane 1 the third, etc.

Continue this study until the end of the 2- or 3-hour period.

FRIDAY PEAK STUDY 3

The third person will count the vehicles traveling past Station 5 or Station 6 (depending upon which lane is closed) during the 2- or 3-hour study period. Use Form B1 to record the counts every 15 minutes. Be sure you group the vehicles into Cars (C) or Trucks (T) just like you did in during Friday Peak Study 1. Position yourself so that you can see whether vehicles are backing up because of the lane closure. Make a note each 15-minute period to indicate whether vehicles were backed up throughout the 15-minute period. There is a special column on Form B1 to record information about the queues.

FRIDAY OR SUNDAY OFF-PEAK STUDY 1

Starting at a time specified by Dr. Dudek, make the necessary measurements to complete Form A. It will take two persons to make the measurements. Some distances such as the width of a lane will be measured in feet and inches with a tape measure; other distances such as the length of the lane closure will be measured to the nearest one-tenth of a mile with the odometer of your car.

FRIDAY OR SUNDAY OFF-PEAK STUDY 2

Starting at a time specified by Dr. Dudek, use Form C to sample the vehicle occupancy--the number of people in the vehicles traveling on the highway. Collect data in the heavy traffic Direction until you record 100 vehicles. As a vehicle passes, count the number of people in the vehicle and place a check mark in the proper cell on Form C. You are going to be sampling, therefore you do not have to record every vehicle that passes. You might look at every third or fourth vehicle and record the number of people until you reach 100 vehicles. Remember to record in the proper cell. There is a place for cars, vans, trucks and buses.

After you record 100 vehicles, repeat the study in the opposite Direction. Again, record the vehicle occupancy for 100 vehicles.

SUNDAY PEAK STUDY 1

Starting at a time specified by Dr. Dudek, collect two or three hours (specified by Dr. Dudek) of traffic counts on the highway in the direction of the peak traffic flow. This will be at either Location 1+2 (See Form B1) or Location 3+4 depending upon which direction the peak traffic is going.

The counts must be made far enough before (upstream) the construction zone so that none of the vehicles must slow down because of backups from the construction zone. In other words, the counts are far enough upstream of the work zone and at a location where none of the drivers must reduce their speeds. You must use good judgement in selecting the count location. Remember, the backup may not take place until after you start counting. So be sure you leave enough distance for a certain amount of backup to occur.

Just like you did for Friday Peak Study 1, you will separate your counts into two groups: Cars (C) and Trucks (T). The following vehicles will be counted as Cars and recorded in the "C" column on Form B1: cars, vans, pickup trucks, and small trucks with 2 axles. Trucks with 3 or more axles and buses will be counted as Trucks and recorded in the "T" column.

Data are recorded on Form B1. Record the counts every 15 minutes. You should not reset the counters until the end of the 2- or 3-hour study. Simply cummulate the counts. The counts can be made and recorded by one person. Make sure you make a note on Form B1 during each 15-minute period that the traffic queue comes near your count station. Continue the counts until the 2- or 3-hour period is over.

SUNDAY PEAK STUDY 2

The second person uses Form C to record (1) the length of queue (backup) measured from the beginning of the lane closure (barricade or cone taper), and (2) the travel time through the construction zone. You will use the car odometer (mileage indicator) to determine the distance of the queue, and your watch or a stop watch to determine the travel times. Starting at the time specified by Dr. Dudek, simply drive your car in traffic in the heavy traffic Direction (See Form B1) on one of the lanes. When you arrive at the tail end of the queue, note and record (1) the odometer reading to the nearest one- tenth of a mile and (2) the time on your watch. (If you are using a stop watch turn the watch on at this point.) If there is no backup make a note on the Form. You must have a record for every run.

Stay in the lane and move in traffic. When you reach the beginning of the lane closure (taper), record (1) the odometer reading and (2) the time on your watch or stop watch.

Drive through the construction zone. When you arrive at the end of the lane closure record (1) the odometer reading and (2) the time.

Then turn around and travel in the opposite Direction. After you pass the construction area and the backup in the heavy traffic Direction, turn around and make another run in the heavy traffic Direction in a different lane. Repeat the data collection procedure. However, each time you make a run, use a different lane. That is drive lane 1 the first time, lane 2 the second time, lane 1 the third, etc. Continue this study until the 2- or 3- hour period is over.

SUNDAY PEAK STUDY 3

The third person counts the vehicles traveling past Station 5 or Station 6 (depending upon which lane is closed) during the 2- or 3-hour study period. Use Form B1 to record the counts every 15 minutes. Be sure you group the vehicles into Cars (C) or Trucks (T) just like you did during Friday Peak Study 1. Position yourself so that you can see whether vehicles are backing up because of the lane closure. Make a note each 15-minute period to indicate whether vehicles were backed up throughout the 15-minute period. There is a special column on Form B1 to record information about the queues.

FIELD DATA COLLECTION INSTRUCTIONS
WEEKEND
TWO-LANE, TWO-WAY OPERATIONS

Weekend Studies

There will be some study construction sites where the peak traffic periods occur on weekends--Friday afternoons and evenings with traffic moving away from large cities, and Sunday afternoons and evenings with traffic moving toward the large cities. Therefore data will be collected on Friday and Sunday at these sites, rather than during the week. Also, three people will be required to collect data on weekends. Note: One additional person must be used for every entrance (on) or exit (off) ramp where traffic counts must be made.

Period of Time

Field data will be collected on Friday afternoon and evening and on Sunday afternoon and evening for Two-Lane, Two-Way Operation traffic control plans. The starting time may be different at each study site; however, it is expected that the study will be conducted somewhere between 3 p.m. and 8 p.m. Dr. Dudek will determine the starting time for each weekend study. You are to contact him for instructions.

Two-Lane, Two-Way Operation In The Outbound Direction

Friday
1. Travel To Study Site
2. Conduct Friday Off-Peak Study 1
3. Conduct Friday Off-Peak Study 2
4. Conduct Friday Peak Study 1
5. Conduct Friday Peak Study 2
6. Conduct Friday Peak Study 3
7. Return Home

Sunday
8. Travel To Study Site
9. Conduct Sunday Peak Study 1
10. Conduct Sunday Peak Study 2
11. Conduct Sunday Peak Study 3
12. Return Home

Two-Lane, Two-Way Operation In The Inbound Direction

Friday
1. Travel To Study Site
2. Conduct Friday Peak Study 1
3. Conduct Friday Peak Study 2
4. Conduct Friday Peak Study 3
5. Return Home

Sunday
6. Travel To Study Site
7. Conduct Sunday Off-Peak Study 1
8. Conduct Sunday Off-Peak Study 2
9. Conduct Sunday Peak Study 1
10. Conduct Sunday Peak Study 2
11. Conduct Sunday Peak Study 3
12. Return Home

WEEKEND
TWO-LANE, TWO-WAY OPERATION STUDY DETAILS

FRIDAY PEAK STUDY 1

Starting at the time specified by Dr. Dudek, collect two or three hours (specified by Dr. Dudek) of traffic counts on the highway in the direction of the peak traffic flow. This will be at either Location 1+2 or Location 3+4 in the Northbound, Southbound, Eastbound, or Westbound heavy traffic Direction, whichever applies (See Form B2).

The counts must be made far enough before (upstream) the construction zone to assure that none of the vehicles must slow down because of backups from the construction zone. In other words, the counts are far enough upstream of the work zone and at a location where none of the drivers must reduce their speeds. You must use good judgement in selecting the count location. Remember, the backup may not take place until after you start counting. So be sure you leave enough distance for a certain amount of backup to occur.

You will separate your counts into two groups: Cars (C) and Trucks (T). The following vehicles will be counted as Cars and recorded in the "C" column on Form B2: cars, vans, pickup trucks, and small trucks with 2 axles. Trucks with 3 or more axles and buses will be counted as Trucks and recorded in the "T" column.

Data are recorded on Form B2. Record the counts every 15 minutes. You should not reset the counters until the end of the 2- or 3-hour study. Simply cummulate the counts. The counts can be made and recorded by one person. Make sure you make a note on Form B2 during each 15-minute period that the traffic queue comes near your count station. Continue the counts until the 2- or 3-hour study period ends.

FRIDAY PEAK STUDY 2

The second person uses Form C to record (1) the length of queue (backup) measured from the beginning of the lane closure (barricade or cone taper), and (2) the travel time through the construction zone. You will use the car odometer (mileage indicator) to determine the distance of the queue, and your watch or a stop watch to determine the travel times. Starting at the time specified by Dr. Dudek, simply drive your car in traffic in the heavy traffic Direction (See Form B2) on one of the lanes. When you arrive at the tail end of the queue, note and record (1) the odometer reading to the nearest one- tenth of a mile and (2) the time on your watch to the nearest second. (If you are using a stop watch turn the watch on at this point.) If there is no backup make a note a note on the Form. You must have a record for every run.

Stay in the lane and move in traffic. When you reach the beginning of the lane closure (taper), record (1) the odometer reading and (2) the time on your watch or stop watch.

Drive through the construction zone. When you arrive at the end of the lane closure record (1) the odometer reading and (2) the time.

Then turn around and travel in the opposite Direction. Collect and record the same type data in the opposite Direction as you did in the heavy traffic Direction.

After you pass through the lane closure in the opposite Direction, turn around and make another run in the heavy traffic Direction in a different lane. Repeat the data collection procedure. However, each time you make a run, use a different lane. That is drive lane 1 the first time, lane 2 the second time, lane 1 the third, etc. Continue this study until the 2- or 3- hour study period ends.

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FRIDAY PEAK STUDY 3

The third person counts the vehicles traveling past Station 5 or Station 6 (depending upon which lane is closed) during the 2- or 3-hour study period. Use Form B2 to record the counts every 15 minutes. Be sure you group the vehicles into Cars (C) or Trucks (T) just like in Friday Peak Study 1. Position yourself so that you can see whether vehicles are backing up because of the lane closure. Make a note each 15-minute period to indicate whether vehicles were backed up throughout the 15-minute period. There is a special column on Form B2 to record information about the queues.

FRIDAY OR SUNDAY OFF-PEAK STUDY 1

Make the necessary measurements to complete Form A. It will take two persons to make the measurements. Some distances such as the width of a lane will be measured in feet and inches with a tape measure; other distances such as the length of the lane closure will be measured to the nearest one-tenth of a mile with the odometer of your car.

FRIDAY OR SUNDAY OFF-PEAK STUDY 2

Use Form D to sample the vehicle occupancy--the number of people in the vehicles traveling on the highway. Collect data in the heavy traffic Direction until you record 100 vehicles. As a vehicle passes, count the number of people in the vehicle and place a check mark in the proper cell on Form D. You are going to be sampling, therefore you do not have to record every vehicle that passes. You might look at every third or fourth vehicle and record the number of people until you reach 100 vehicles. Remember to record in the proper cell. There is a place for cars, vans, trucks and buses.

After you record 100 vehicles, repeat the study in the opposite Direction. Again, record the vehicle occupancy for 100 vehicles.

SUNDAY PEAK STUDY 1

Starting at the time specified by Dr. Dudek, collect two or three hours (specified by Dr. Dudek) of traffic counts on the highway in the direction of the peak traffic flow. This will be at either Location 1+2 (See Form B2) or Location 3+4 depending upon which direction the peak traffic is going.

The counts must be made far enough before (upstream) the construction zone so that none of the vehicles must slow down because of backups from the construction zone. In other words, the counts are far enough upstream of the work zone and at a location where none of the drivers must reduce their speeds. You must use good judgement in selecting the count location. Remember, the backup may not take place until after you start counting. So be sure you leave enough distance for a certain amount of backup to occur.

Just like you did for Friday Peak Study 1, you will separate your counts into two groups: Cars (C) and Trucks (T). The following vehicles will be counted as Cars and recorded in the "C" column on Form B2: cars, vans, pickup trucks, and small trucks with 2 axles. Trucks with 3 or more axles and buses will be counted as Trucks and recorded in the "T" column.

Data are recorded on Form B2. Record the counts every 15 minutes. You should not reset the counters until the end of the 2- or 3-hour study. Simply cummulate the counts. The counts can be made and recorded by one person. Make sure you make a note on Form B2 during each 15-minute period that the traffic queue comes near your count station. Continue the counts until the 2- or 3-hour study period ends.

SUNDAY PEAK STUDY 2

The second person uses Form C to record (1) the length of queue (backup) measured from the beginning of the lane closure (barricade or cone taper), and (2) the travel time through the construction zone. You will use the car odometer (mileage indicator) to determine the distance of the queue, and your watch or a stop watch to determine the travel times. Starting at the time specified by Dr. Dudek, simply drive your car in traffic in the heavy traffic Direction (See Form B2) on one of the lanes. When you arrive at the tail end of the queue, note and record (1) the odometer reading to the nearest one- tenth of a mile and (2) the time on your watch. (If you are using a stop watch turn the watch on at this point.) If there is no backup make a note on the Form. You must have a record for every run.

Stay in the lane and move in traffic. When you reach the beginning of the lane closure (taper), record (1) the odometer reading and (2) the time on your watch or stop watch.

Drive through the construction zone. When you arrive at the end of the lane closure record (1) the odometer reading and (2) the time.

Then turn around and travel in the opposite Direction. Collect and record the same data in the opposite Direction as you did for the heavy traffic Direction.

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After you pass the construction area and the backup in the heavy traffic Direction, turn around and make another run in the heavy traffic Direction in a different lane. Repeat the data collection procedure. However, each time you make a run, use a different lane. That is drive lane 1 the first time, lane 2 the second time, lane 1 the third, etc. Continue this study until the 2- or 3-hour study period ends.

SUNDAY PEAK STUDY 3

The third person counts the vehicles traveling past Station 5 or Station 6 (depending upon which lane is closed) during the 2-or 3-hour study period. Use Form B2 to record the counts every 15 minutes. Be sure you group the vehicles into Cars (C) or Trucks (T) just like you did during Friday Peak Study 1. Position yourself so that you can see whether vehicles are backing up because of the lane closure. Make a note each 15-minute period to indicate whether vehicles were backed up throughout the 15-minute period. There is a special column on Form B2 to record information about the queues.

FIELD DATA COLLECTION INSTRUCTIONS
HOLIDAY WEEKEND
TWO-LANE, TWO-WAY OPERATIONS

Holiday Weekend Studies

There will be some study construction sites where the peak traffic periods occur on holiday weekends--Friday afternoons and evenings with traffic moving away from large cities, and Monday afternoons and evenings with traffic moving toward the large cities. Therefore data will be collected on Friday and Monday at these sites, rather than during the week. Also, three people will be required to collect data on holiday weekends. Note: One additional person must be used for every entrance (on) or exit (off) ramp where traffic counts must be made.

Period of Time

Field data will be collected on Friday afternoon and evening and on Monday afternoon and evening for Two-Lane, Two-Way Operation traffic control plans. The starting time may be different at each study site; however, it is expected that the study will be conducted somewhere between 3 p.m. and 8 p.m. Dr. Dudek will determine the starting time for each holiday weekend study. You are to contact him for instructions.

Two-Lane, Two-Way Operation In The Outbound Direction

Friday
1. Travel To Study Site
2. Conduct Friday Off-Peak Study 1
3. Conduct Friday Off-Peak Study 2
4. Conduct Friday Peak Study 1
5. Conduct Friday Peak Study 2
6. Conduct Friday Peak Study 3
7. Return Home

Monday
8. Travel To Study Site
9. Conduct Monday Peak Study 1
10. Conduct Monday Peak Study 2
11. Conduct Monday Peak Study 3
12. Return Home

Two-Lane, Two-Way Operation In The Inbound Direction

Friday
1. Travel To Study Site
2. Conduct Friday Peak Study 1
3. Conduct Friday Peak Study 2
4. Conduct Friday Peak Study 3
5. Return Home

Monday
6. Travel To Study Site
7. Conduct Monday Off-Peak Study 1
8. Conduct Monday Off-Peak Study 2
9. Conduct Monday Peak Study 1
10. Conduct Monday Peak Study 2
11. Conduct Monday Peak Study 3
12. Return Home

HOLIDAY WEEKEND
TWO-LANE, TWO-WAY OPERATION STUDY DETAILS

FRIDAY PEAK STUDY 1

Starting at the time specified by Dr. Dudek, collect two or three hours (specified by Dr. Dudek) of traffic counts on the highway in the direction of the peak traffic flow. This will be at either Location 1+2 or Location 3+4 in the Northbound, Southbound, Eastbound, or Westbound heavy traffic Direction, whichever applies (See Form B2).

The counts must be made far enough before (upstream) the construction zone to assure that none of the vehicles must slow down because of backups from the construction zone. In other words, the counts are far enough upstream of the work zone and at a location where none of the drivers must reduce their speeds. You must use good judgement in selecting the count location. Remember, the backup may not take place until after you start counting. So be sure you leave enough distance for a certain amount of backup to occur.

You will separate your counts into two groups: Cars (C) and Trucks (T). The following vehicles will be counted as Cars and recorded in the "C" column on Form B2: cars, vans, pickup trucks, and small trucks with 2 axles. Trucks with 3 or more axles and buses will be counted as Trucks and recorded in the "T" column.

Data are recorded on Form B2. Record the counts every 15 minutes. You should <u>not</u> reset the counters until the end of the 2- or 3-hour study. Simply cummulate the counts. The counts can be made and recorded by one person. Make sure you make a note on Form B2 during each 15-minute period that the traffic queue comes near your count station. Continue the counts until the 2- or 3-hour study period ends.

FRIDAY PEAK STUDY 2

The second person uses Form C to record (1) the length of queue (backup) measured from the beginning of the lane closure (barricade or cone taper), and (2) the travel time through the construction zone. You will use the car odometer (mileage indicator) to determine the distance of the queue, and your watch or a stop watch to determine the travel times. Starting at the time specified by Dr. Dudek, simply drive your car in traffic in the heavy traffic Direction (See Form B2) on one of the lanes. When you arrive at the tail end of the queue, note and record (1) the odometer reading to the nearest one- tenth of a mile and (2) the time on your watch to the nearest second. (If you are using a stop watch turn the watch on at this point.) If there is no backup make a note a note on the Form. You must have a record for every run.

Stay in the lane and move in traffic. When you reach the beginning of the lane closure (taper), record (1) the odometer reading and (2) the time on your watch or stop watch.

Drive through the construction zone. When you arrive at the end of the lane closure record (1) the odometer reading and (2) the time.

Then turn around and travel in the opposite Direction. Collect and record the same type data in the opposite Direction as you did in the heavy traffic Direction.

After you pass through the lane closure in the opposite Direction, turn around and make another run in the heavy traffic Direction in a different lane. Repeat the data collection procedure. However, each time you make a run, use a different lane. That is drive lane 1 the first time, lane 2 the second time, lane 1 the third, etc. Continue this study until the 2- or 3- hour study period ends.

FRIDAY PEAK STUDY 3

The third person counts the vehicles traveling past Station 5 or Station 6 (depending upon which lane is closed) during the 2- or 3-hour study period. Use Form B2 to record the counts every 15 minutes. Be sure you group the vehicles into Cars (C) or Trucks (T) just like in Friday Peak Study 1. Position yourself so that you can see whether vehicles are backing up because of the lane closure. Make a note each 15-minute period to indicate whether vehicles were backed up throughout the 15-minute period. There is a special column on Form B2 to record information about the queues.

FRIDAY OR MONDAY OFF-PEAK STUDY 1

Make the necessary measurements to complete Form A. It will take two persons to make the measurements. Some distances such as the width of a lane will be measured in feet and inches with a tape measure; other distances such as the length of the lane closure will be measured to the nearest one-tenth of a mile with the odometer of your car.

FRIDAY OR MONDAY OFF-PEAK STUDY 2

Use Form D to sample the vehicle occupancy--the number of

people in the vehicles traveling on the highway. . Collect data in the heavy traffic Direction until you record 100 vehicles. As a vehicle passes, count the number of people in the vehicle and place a check mark in the proper cell on Form D. You are going to be sampling, therefore you do not have to record every vehicle that passes. You might look at every third or fourth vehicle and record the number of people until you reach 100 vehicles. Remember to record in the proper cell. There is a place for cars, vans, trucks and buses.

After you record 100 vehicles, repeat the study in the opposite Direction. Again, record the vehicle occupancy for 100 vehicles.

MONDAY PEAK STUDY 1

Starting at the time specified by Dr. Dudek, collect two or three hours (specified by Dr. Dudek) of traffic counts on the highway in the direction of the peak traffic flow. This will be at either Location 1+2 (See Form B2) or Location 3+4 depending upon which direction the peak traffic is going.

The counts must be made far enough before (upstream) the construction zone so that none of the vehicles must slow down because of backups from the construction zone. In other words, the counts are far enough upstream of the work zone and at a location where none of the drivers must reduce their speeds. You must use good judgement in selecting the count location. Remember, the backup may not take place until after you start counting. So be sure you leave enough distance for a certain amount of backup to occur.

Just like you did for Friday Peak Study 1, you will separate your counts into two groups: Cars (C) and Trucks (T). The following vehicles will be counted as Cars and recorded in the "C" column on Form B2: cars, vans, pickup trucks, and small trucks with 2 axles. Trucks with 3 or more axles and buses will be counted as Trucks and recorded in the "T" column.

Data are recorded on Form B2. Record the counts every 15 minutes. You should <u>not</u> reset the counters until the end of the 2- or 3-hour study. Simply cummulate the counts. The counts can be made and recorded by one person. Make sure you make a note on Form B2 during each 15-minute period that the traffic queue comes near your count station. Continue the counts until the 2- or 3-hour study period ends.

MONDAY PEAK STUDY 2

The second person uses Form C to record (1) the length of queue (backup) measured from the beginning of the lane closure (barricade or cone taper), and (2) the travel time through the construction zone. You will use the car odometer (mileage indicator) to determine the distance of the queue, and your watch or a stop watch to determine the travel times. Starting at the time specified by Dr. Dudek, simply drive your car in traffic in the heavy traffic Direction (See Form B2) on one of the lanes. When you arrive at the tail end of the queue, note and record (1) the odometer reading to the nearest one- tenth of a mile and (2) the time on your watch. (If you are using a stop watch turn the watch on at this point.) If there is no backup make a note on the Form. You must have a record for every run.

Stay in the lane and move in traffic. When you reach the beginning of the lane closure (taper), record (1) the odometer reading and (2) the time on your watch or stop watch.

Drive through the construction zone. When you arrive at the end of the lane closure record (1) the odometer reading and (2) the time.

Then turn around and travel in the opposite Direction. Collect and record the same data in the opposite Direction as you did for the heavy traffic Direction.

After you pass the construction area and the backup in the heavy traffic Direction, turn around and make another run in the heavy traffic Direction in a different lane. Repeat the data collection procedure. However, each time you make a run, use a different lane. That is drive lane 1 the first time, lane 2 the second time, lane 1 the third, etc. Continue this study until the 2- or 3-hour study period ends.

MONDAY PEAK STUDY 3

The third person counts the vehicles traveling past Station 5 or Station 6 (depending upon which lane is closed) during the 2-or 3-hour study period. Use Form B2 to record the counts every 15 minutes. Be sure you group the vehicles into Cars (C) or Trucks (T) just like you did during Friday Peak Study 1. Position yourself so that you can see whether vehicles are backing up because of the lane closure. Make a note each 15-minute period to indicate whether vehicles were backed up throughout the 15-minute period. There is a special column on Form B2 to record information about the queues.