Table 1. Channelizing device designs selected from field test results.

Test No.	I-81, Cedar Creek, 40-ft spacing	W.L.C.D.[a]	I-81, Narrow Passage, 80-ft spacing	W.L.C.D.[a]
1	Type I chevron	8.8	Type I chevron	20.0
2	Type II chevron Type III diagonal	0.3	Type II chevron Type III diagonal	2.5
3	Drum panel	8.7	Chevron panel	11.3
4	Diagonal panel Chevron panel	2.4	Chevron panel Diagonal panel	3.3

Note: The listing of two channelizing devices indicates equal ratings.
[a]W.L.C.D. = Difference in weighted lane changes between the preferred pattern and less preferred patterns.

work zone safety (2,3), bridge work and pavement reconstruction are associated with a greater increase in accident rates than are other construction activities. The typical work zone setup for these activities in Virginia employs a New Jersey concrete barrier and flashing arrow panel. Since the channelizing devices were being tested while serving as a supplement to the New Jersey barrier, a supplemental taper seemed to be an obvious alternative. The New Jersey barrier was rated equal to the cone for day only and lower than all other devices based on the weighted lane changes. Steady-burn beacons and reflectors about 6 in long were mounted on the New Jersey barrier, which had a slope of 16:1 for the 192-ft taper. The recommendation to use a supplemental taper with the New Jersey barrier will be included in the Virginia supplement of the Manual on Uniform Traffic Control Devices (4).

CONCLUSION

The results of this study do not support a recommendation that the chevron patterns be used on all channelizing devices. Except for those relating to the type I chevron barricade, the conclusions do not clearly and consistently favor the chevron patterns. Since, in general, distinct differences in effectiveness are not attributable to the differences in patterns used on a specific type of device, panel, or barricade, we may conclude that the effectiveness of a channelizing device is not based primarily on the pattern used. The chevron patterns generally were rated slightly better or equal to the currently used patterns with which they were compared. The responses of drivers as measured by the position of lane changing were similar for the two types of patterns.

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Effectiveness of City Traffic-Control Programs for Construction and Maintenance Work Zones

JOHN VAN WINKLE AND JACK B. HUMPHREYS

The purpose of this study was to evaluate the present state of the art of city traffic-control programs for construction and maintenance work zones. Information was gathered through two separate investigations to determine the status of present city traffic-control programs for construction and maintenance work zones and the effectiveness of these programs. A survey was conducted by sending questionnaires to cities in the United States that asked for information related to various aspects of the cities' traffic-control programs in work zones. Responses were rated according to each city's degree of involvement in regulating traffic controls in work zones. The results indicated that the amount of importance cities place on traffic-control progrms for work zones varies widely and the majority of the cities surveyed do a less-than-adequate job in controlling construction and maintenance activity. Work zones in eight of the surveyed cities were studied to evaluate the effectiveness of the cities' traffic-control programs for work zones. This information was used to rate each of the cities' effectiveness and compare it with the survey ratings by using a statistical ranking procedure. A correlation was found between the survey scores and the field investigation scores. This correlation suggests that the quality of traffic control in the work zones is dependent on the degree of involvement the cities have in regulating construction and maintenance work zones.

With the recent shift of emphasis from the construction of new highways to the rehabilitation and upgrading of existing facilities, a significant effort has been made to improve the quality of traffic control through road construction and maintenance work zones. Much research has been performed to develop more-effective devices for traffic control and standards to use them. As a result of this research, several changes have been made in the Manual on Uniform Traffic Control Devices (MUTCD) (1) and in Federal Highway Administration (FHWA) guidelines for federally funded construction projects.

Since the adoption of this MUTCD, studies are beginning to show that, to a large degree, the standards for traffic-control devices for construction and maintenance work zones and the requirements for their proper use are adequate. A major FHWA research effort conducted by the University of Tennessee, which inspired this study, identified and evaluated more than 100 work zones in 11 states across the United States. It determined that (2) "over two-thirds (of the individual deficiencies identified)...were considered to be adequately addressed in the Manual on Uniform Traffic Control Devices or by the current state of the art."

Another study, conducted by the U.S. General Accounting Office, reviewed efforts by FHWA to increase safety through road construction work zones. This study found that at all levels (3)

1. Officials did not always know how to make work sites safe,
2. They did not always appreciate the need for safety, and
3. They placed higher priority on construction quality, economy, and deadlines.

The review recommended that MUTCD be revised to include specific management guidelines for the implementation of traffic-control measures in work zones.

Many of the major problems researchers are finding lie not with the standards but with management's effort to adequately encourage and enforce better adherence to the standards. To quote a recent Kentucky study (4), "Jobsite safety, as with traffic accident prevention overall, is only as good as its administration follow-through."

Recent research at the University of Tennessee has reviewed the current status of traffic-control programs for cities across the country. This paper analyzes the existing city programs along with field investigations of sites within eight of the surveyed cities.

STATE OF THE ART

In order to determine the current state of the art of city traffic-control programs for construction and maintenance work zones, a survey was made of city traffic engineers throughout the United States. One hundred randomly selected cities that have populations that range between 50 000 and 1 000 000 were sent questionnaires, and 49 questionnaires were returned. Although the cities were selected on a near random basis, effort was made to obtain questionnaires from cities that were reviewed in the related FHWA study (2) for comparative use in this research.

Twelve questions related to various aspects of the cities' traffic-control management programs for work zones were asked. The questions covered four general areas:

1. Permit and authorization procedures;
2. Development, approval, and implementation of a traffic-control plan and field inspection;
3. Enforcement and training policies; and
4. General problems and areas for improvement identified by the cities.

All questions and a summary of the results of the survey are shown in Figure 1.

The responses to the survey were broken down into two categories--rated and nonrated questions. The five rated questions (1, 4, 5, 8, and 10) were asked to determine how active a role the cities had in regulating the traffic control for construction and maintenance activity within the street right-of-way. The remaining questions were asked to determine what the typical practices were, but the responses did not give an indication of good or bad procedures and were not rated.

Figure 1. Summary of survey results.

1. Do you have a permit for street closures incorporating traffic control requests?

   No 33%
   Yes, without traffic control requirements. 22%
   Yes, with traffic control requirements 45%

2. What advance notice do you require for street closures (minor closures--total closure of a local street or partial closure of collector streets, major closures--total closures of collector or total or partial closure of arterial streets)?

	Number of Cities		
	Minor or Major Closures	Minor Closures	Major Closures
None	5	-	-
24 hours	-	17	6
48 hours	-	10	6
72 hours	-	-	8
1 week	-	-	7
2 weeks	-	-	2
Other	2	-	-

3. Under what circumstances is a permit not required?

   None/none required 43%
   Emergency work 41%
   Utility/city forces/contract work. 10%
   Special cases w/verbal OK. 6%

4. Is your department actively involved in traffic control plan inspection and/or approval?

   No 10%
   Yes, minor involvement 63%
   Yes, major involvement 27%

5. Does your department have any employees whose primary duty is to approve traffic control layouts and inspect work zone traffic controls?

   No 49%
   No, employee(s) w/partial duty 29%
   Yes. 22%

6. Who is responsible to develop traffic control plans?

   Contractor/utilities 65%
   Traffic engineering department 35%

7. Does your department provide traffic control devices for work done by your department and/or other agencies?

   City forces only 45%
   Department only, or no one 41%
   Others 14%

8. What are your enforcement policies and penalties for work without a permit and/or non-compliance with an approved plan?

   None 24%
   Shut down job. 45%
   Shut down job plus fine, arrest and/or revoke permit. 12%
   Other (combination of fine, revoke permit, arrest). 20%

9. Do you have a city manual specifically for traffic control in work zones?

   No 53%
   Yes. 45%
   No response. 2%

10. Do you regularly conduct any kind of training program for your employees and/or other agencies?

    No 51%
    Occasionally 10%
    Yes, only to city forces 14%
    Yes. 24%

11. What problems are you having with your program, and what improvements would you like to see made?

    Number of Cities

    Non-compliance/poor signing procedures 14
    Lax enforcement. 10
    Insufficient inspection. 9
    Inadequate training. 7
    Poor notification/coordination 7
    Weak ordinances to force compliance. 7
    Convincing contractors of need for proper traffic control. 3

12. How would you rate your city's traffic control program?

    Insufficient 29%
    Adequate .69%
    Excellent. 0%
    No response. 2%

Table 1. Ratings for questionnaire responses.

Question[a]	Weighting	Response	Score
1	10	No	0
		Yes, without traffic control requirements	5
		Yes, with traffic control requirements	10
2		Not rated	
3		Not rated	
4	25	None	0
		Minor involvement	10
		Major involvement	25
5	30	None	0
		Partial	15
		Primary	30
6		Not rated	
7		Not rated	
8	10	None	0
		Penalty	10
9		Not rated	
10	25	None	0
		Conducted occasionally	10
		Conducted regularly for city forces only	15
		Yes, open to all agencies	25
11		Not rated	
12		Not rated	
Total	100		

[a]See Figure 1 for questions.

Of the five rated questions, the question that asked whether the cities had personnel whose primary responsibility involved traffic-control planning and inspection for work zones gave the best indication of a city's commitment to regulating traffic control in work zones. Of the 100 points possible, this question was given the highest weighting of 30 points.

Two questions, involving traffic-control plan inspection and approval and training programs, were also considered to be of major importance and were given a weighting of 25 points each. The last two questions, which dealt with permits for street closure and enforcement policies, gave indications of the cities' involvement in these programs to a minor degree and, therefore, were given a lower rating of 10 points each. A listing of the ratings and a breakdown of partial scoring are shown in Table 1.

Although a weighting of the questions was made based on the relative importance of each, the relative rankings of the cities were unaffected by the weighting. That is, cities that scored high on the major (heavier weighted) questions also scored higher on the lower value questions. Cities that received no points or part scores on the major questions scored similarly on the minor questions.

The results of the scoring of the responses are shown graphically in Figure 2, which indicates that the variation in the cities' scores is wide. The average score for all cities was 46.2 points. If we assume that the bare minimum programs require 60 points (part scores on the three major questions and full scores on the two minor questions), 71 percent of the cities had less than adequate programs. In fact, this same percentage scored 50 points or less.

A significant finding of this phase of the study was that, despite the fact that the majority of the city traffic-control programs for work zones were considered to be less than satisfactory, 60 percent of the cities thought that they had an adequate program.

FIELD INVESTIGATIONS

The next phase of the research was to evaluate the quality of traffic control through urban work zones by using actual field investigations and then to compare the results of these investigations with the survey results. The information used for this analysis was acquired by the University of Tennessee (2).

As part of this FHWA study, 103 construction, maintenance, or utility work zones in 11 states were visited. Data collected from these sites covered many types of conditions, including urban and rural locations, day and night-time activities, stationary and moving operations, and various types of work zones (e.g., roadside, lane closures, and detours) and facilities (two-lane, multilane, and Interstate).

Data were gathered by field investigators through the use of several methods. These methods included use of a data checklist in which various conditions of the site were noted, interviews of workers and local government officials, and documentation of these conditions through extensive use of 35-mm photography.

After an investigator made field investigations, he or she led a panel review by using the 35-mm slides to explain the nature of the work. The panel for each review was composed of a minimum of four professionals experienced in the field of traffic safety. Deficiencies for each site were noted and then rated by the panel according to three parameters--hazard, risk, and preventability. These parameters were defined in the report as follows (2):

> Hazard was understood to be a measure of severity, and risk the probability that an accident would occur. Preventability was understood to reflect the degree to which the hazard and risk associated with the problem would have been reduced had all applicable codes and standard practices been followed and/or current knowledge utilized.

Each of these factors was rated by each panel member on a scale of 0-5. A hazard that rated zero indicated no hazard, and five indicated a very serious safety problem. Similarly, a rating of zero on the risk scale indicated that there was a zero probability that an accident would occur, and a five meant that the probability of an accident occurring was very high. A preventability score of zero indicated that there existed no information as to how the problem could have been corrected and a five suggested that the deficiency could have been eliminated had current standards been followed. These ratings were then recorded on a work zone inspection summary sheet for each site.

Eight cities were common to both the FHWA study and the survey conducted for this research and covered a total of 30 work zones. Four of the cities had only 1 or 2 sites; the remaining four cities had 5-7 sites each. Eighteen of the sites were construction work zones and 12 were utility work zones. Two of the cities had no construction sites and two others had no utility sites. No maintenance work zones were included in this sample.

By using the ratings determined by the previous study, a composite score was calculated for each deficiency of each project by multiplying the average scores for each of the three factors. This product reflected the severity of a given problem area at any given work site. For example, for a score of 1, 1, and 5, the Hazard x Risk x Preventability score was 5. This score reflected that there was very little hazard and risk and that the deficiency could have been corrected by using existing knowledge. As another extreme example, individual scores of 5, 5, and 0 yielded a product score of zero. In this case, although the hazard and risk were very high, because no current information was available on how to treat the given problem, the city was not penalized. These scores were then

Figure 2. Distribution of survey scores.

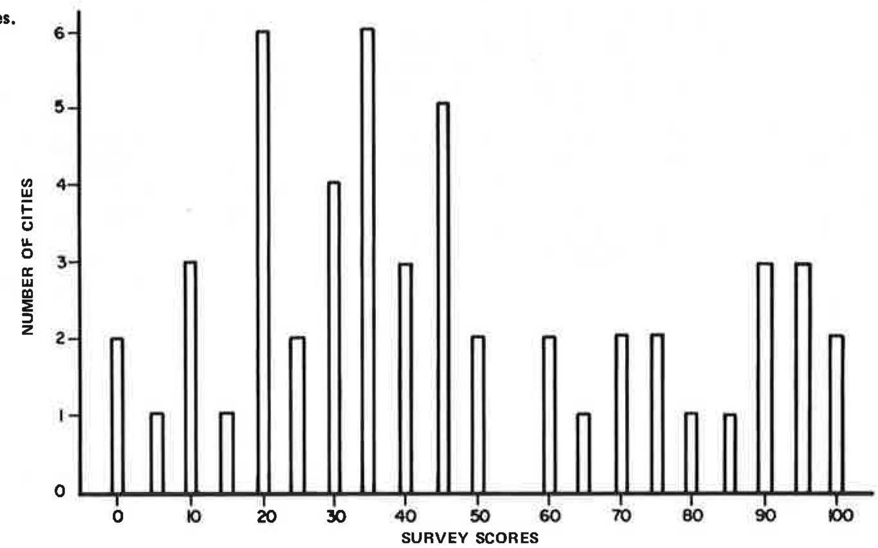

Table 2. Summary of survey and field investigation scores.

		Hazard x Risk x Probability Score		
City	Questionnaire Survey Score	Construction Work Zone	Utility Work Zone	Average
A	50		15.87	15.87
B	40	26.10	27.73	26.93
C	100	23.04	18.45	21.89
D	90		4.67	4.67
E	100	17.04	9.98	15.09
F	20	20.83	20.30	20.70
G	45	26.90		26.90
H	20	27.42		27.42

Table 3. Rank comparisons among survey and product average ratings.

City	Survey Rank	Hazard x Risk x Probability Average Rank	d^2
A	4	3	1.0
B	6	7	1.00
C	1.5	5	12.25
D	3	1	4.00
E	1.5	2	0.25
F	7.5	4	12.75
G	5	6	1.00
H	7.5	8	0.25
			32.00

Notes: $r_S = 1 - [6(32)]/[8(63)] = 0.62$.
Student's $t = 0.62 \sqrt{6/[1 - (0.62)^2]} = 1.94$.
$n = 8$, degrees of freedom = 6.
5 percent confidence interval, critical value = 1.94, $1.94 \geqslant 1.94$; therefore, cannot reject the hypothesis of correlation at 95 percent level of confidence.

averaged for each city for each type of work zone (construction and utility) and for a combined overall score.

In the FHWA study the preventability score was reversed (5-P) following the rating of the problems so that, in the evaluation of the ratings, areas where further research was needed would be identified. A summary of the survey and product scores for this research is given in Table 2.

Having rated the eight cities based on the field investigations, the next step was to compare these results with the survey results to test for correlation. Because the sample size was small, it was felt that tests for correlation by using absolute value scores for comparison would not be meaningful. Instead, it was decided a rank correlation procedure would be the most-appropriate method.

The cities were first ranked from lowest to highest based on the scores they received from the survey results. In cases where two cities had the same score, their rank position was determined by averaging.

In the same manner, the cities were ranked according to the product scores. These rankings are as shown in Table 3.

To measure the degree of association among the rankings, Spearman's r was calculated by using the following formula:

$$r_s = 1 - [6\Sigma d^2/n(n^2 - 1)] \qquad (1)$$

where Σd^2 is the sum of the square of the rank differences and n is the number of cities ranked.

Student's t was then calculated as follows (5):

$$\text{Student's } t = r_s[(n - 2)/(1 - r_s)] \qquad (2)$$

Based on this analysis, correlation of the two rankings could not be rejected at the 95 percent level of confidence.

In summary, the rank correlation between the survey results and the overall field investigation ratings suggests that the quality of the traffic control in work zones is dependent on the degree of involvement the cities have in regulating construction and maintenance work zones. Good traffic management programs for work zones are apparently effective in achieving improvement in traffic control through work zones, and lax programs apparently result in poorer traffic control.

SUMMARY AND RECOMMENDATIONS

The study surveyed cities across the United States to determine their degree of involvement in regulating traffic controls in work zones. The quality of controls in work zones in these cities was also evaluated. A statistical rank correlation between the quality of city traffic management programs for work zones and the quality of the traffic control in work zones was conducted. This comparison was found to be significant and indicates that better traffic management programs result in better traffic control in the field.

Because the survey showed that, in general, the traffic-control management programs are less than adequate, cities need to institute effective programs to regulate street maintenance and construction activity.

Based on this research, if cities make the effort to implement traffic management programs for work zones, the quality of the traffic control through work zones should improve. The need now is to convince cities of the necessity for providing these programs. It is therefore recommended that a more comprehensive study be conducted of city traffic management programs in work zones to determine the needs and inadequacies of these programs and to recommend and test various proposals to improve the programs.

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Concrete Barriers at Transition Zones Adjacent to Two-Way Traffic Operation on Normally Divided Highways

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One technique to control traffic around construction zones on four-lane divided highways is to close one of the roadways for construction work and provide two-way, two-lane operations on the opposite roadway. Because of the high frequency of head-on collisions under this type of traffic control, the Federal Highway Administration issued an emergency rule that, among other things, requires that concrete barriers be placed at the transition zones where four-lane operations change to two-lane and vice versa. The objective of this study was to verify whether barriers are justified at transition zones on the basis of accident experience. Data from 14 rural Interstate work sites showed that no head-on accidents occurred at the transitions but several occurred on the two-way, two-lane segments. This indicates that, at least on lesser-traveled highways, the probability of a head-on collision is low because of the minimal volume of oncoming traffic. Therefore, the barrier requirement is questionable on low-volume roadways. By using intuitive reasoning, the effects of project duration and approach speed on accident behavior in transition zones are also discussed.

Various management strategies have been implemented to control traffic through construction and maintenance work zones on rural, four-lane divided highways. One strategy is to close one roadway for the construction work and provide two-way, two-lane no-passing operations on the opposite roadway. Median crossovers at the transition zones are constructed between the roadways to divert traffic around the closed segment. Refer to Figure 1 for an illustration of the management strategy (1, p. 6B-10).

Under this type of traffic control, an alarming number of severe head-on accidents were found to have occurred (2). As a result, the Federal Highway Administration (FHWA) issued an emergency rule in 1979 that required the use of special traffic control devices along the two-way, two-lane segments and at the transition zones. The rule requires that (3, p. 53 739) "where two-way traffic must be maintained...opposing traffic (must) be separated either with concrete 'safety shape' barriers or with drums, cones, or vertical panels throughout the length of the two-way operation except for transition zones where concrete barriers are to be used in all cases."

This study was concerned with the latter portion of the emergency rule, which requires the use of concrete barriers at all transition zones. The transition zone is defined in this study as the roadway section at which traffic flow is converted from a four- to two-lane operation and vice versa. Because of its traffic flow configuration, transition zones were thought to be susceptible to head-on crashes. The installation of concrete barriers in the transition zone virtually eliminates the possibility of a head-on collision caused by a motorist straying across the centerline.

On the contrary, a number of highway engineers have pointed out the disadvantages with the barriers in response to the FHWA rule (4):

1. The presence of the concrete barriers is a traffic hazard in itself; also, there is an additional hazard during erection and removal of the barriers;
2. Barriers may not be practical in certain situations, such as low traffic volumes, low-speed roadways, or short-term projects;
3. The cost of material and labor for the concrete barrier will increase the project costs;
4. Crash cushions will be required at exposed barrier approach ends and add another fixed-object hazard to the driving environment as well as raise traffic control costs; and