An Evaluation of Portable Traffic Signals at Work Zones

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Portable traffic signal systems are now being marketed by several manufacturers. These systems have the potential for replacing flaggers in many work zones that require alternating one-way traffic control. However, because these systems are relatively new, information is needed about their effect on traffic operations and safety at work-zone locations. The Texas Transportation Institute recently conducted studies of a fixed-time portable signal system at three work-zone lane closures on two-lane, two-way highways. At each site, data were collected on traffic volumes, driver noncompliance with the signals, and vehicle stopped delay. The studies showed that a substantial savings in flagger labor costs could be achieved by using a portable fixed-time signal system with only a minimal increase in motorist delay costs. Conservative estimates of the savings at the study sites ranged from $9 to $14 per hour. The studies also suggested that the potential for vehicle accidents within the work zone may be higher with portable traffic signals because of occasional driver noncompliance with these signals. The trade-off between this possible increase in vehicular accidents and the reduction in flagger accidents could not be estimated from this research.

As a general rule, work-zone lane closures on two-lane, two-way highways require some method of coordinating opposing traffic movements in the remaining open lane *(1)*. Most often this coordination is provided by flaggers stationed at each end of the lane closure. Unfortunately, flagging is a costly method of traffic control, requiring two or more persons continuously for the duration of the closure. In addition, flaggers must work close to moving traffic, which leaves very little room for error by either flagger or driver. Because flagging is such a labor-intensive and hazardous activity, it would be desirable to use other methods of traffic control whenever possible.

Traffic signal systems similar to those installed at intersections have been used in work zones in limited cases as an alternative to the use of flaggers. However, the cost of a traditional traffic signal installation ranges from $25,000 for a fixed-time system to $50,000 for a traffic-activated system. Consequently, traffic signals have only been feasible for long-term stationary work operations. As an example, the Texas State Department of Highways and Public Transportation has generally limited the use of traffic signals to lane closures on restricted-width bridges where construction will take 3 months or longer to complete.

Recently, however, several manufacturers have developed and are now marketing portable traffic signal systems. These systems are free-standing, self-contained, and easily transportable. They are generally simple to set up and program, and are designed to be adaptable to a variety of situations.

Portable traffic signal systems have the potential for replacing flaggers in many work-zone operations requiring control of alternating one-way traffic. However, because these systems are relatively new, experience with them in actual work-zone application has been limited. Information about the effect of portable signal systems on work-zone safety and traffic operations is needed. The Texas Transportation Institute, as part of a study to improve flagger safety sponsored by the Texas State Department of Highways and Public Transportation, recently completed limited field studies of a portable fixed-time traffic signal system at several work-zone lane closures on two-lane, two-way highways. This paper presents the results of these studies.

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STUDY PROCEDURE

Site Description

Portable fixed-time traffic signals were tested at three work-zone locations on two-lane, two-way rural highways (without paved shoulders) in Texas. Maintenance work on the roadway surface at each location required that one travel lane be closed. In each case, portable signals were used instead of flaggers to alternate opposing traffic through the one-lane section. The sites chosen for study represented a range of traffic volumes and work-zone lengths, as shown in Table 1. Also shown in Table 1 are the signal timing settings used at each site. Repairs at study Sites 1 and 2 were 1-day work activities, whereas repairs at Site 3 involved two 1-day lane closures. At Site 3, flaggers were used for traffic control on the first day, and signal control was used on the second.

Sites 1 and 2 had sight distances in excess of 1,000 ft to the work zone on both approaches, whereas severe horizontal and vertical geometry at Site 3 limited sight distance to about 500 ft

TABLE 1 SUMMARY OF TRAFFIC VOLUMES, WORK-ZONE LENGTHS, AND SIGNAL TIMING SETTINGS

Site	Traffic Volumes, 1985 AADT	Work-Zone Length (ft)	Signal Timing Settings (sec)		
			Cycle Length	Green Phase	All-Red Clearance
1	600	600	78	10	26
2	2,400	2,600	246	30	90
3	10,000	1,100	140	30	37

NOTE: AADT = annual average daily traffic.

in either direction. At none of the sites was there visibility from one end of the lane closure to the other. The speed limit at each site was posted at 55 mph, with actual travel speeds very close to this value.

The traffic control plan for the sites was similar to that used for flagger-controlled minor work-zone operations *(1)*, except that an orange-and-black symbolic Signal Ahead sign (W3-3) replaced the Flagger Ahead sign in advance of the closure, as shown in Figure 1.

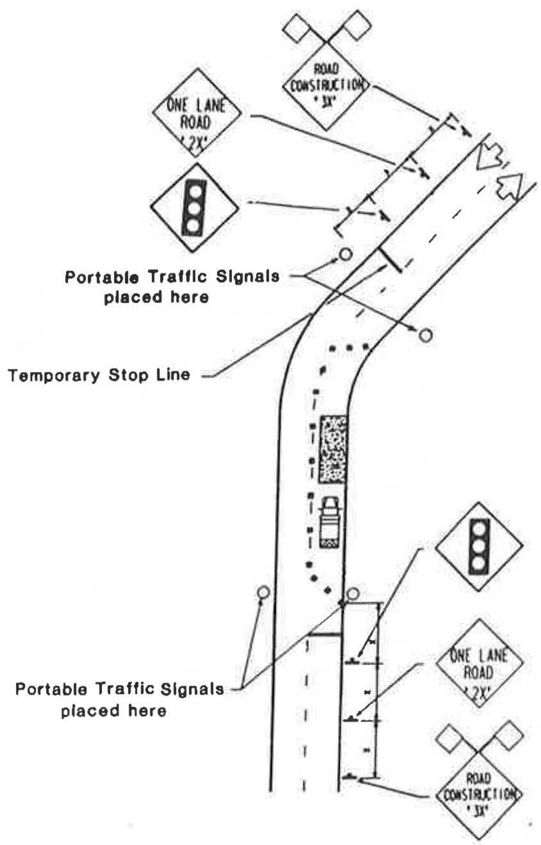

FIGURE 1 Traffic control plan.

Data Collection and Analysis

A variety of data was collected during the setup and operation of the portable signals, including traffic volume, driver compliance with the signals, and vehicle stopped delay. Delay and compliance data were collected for about 4 hr each day during the time that work was actually being performed in the closed lane.

Stopped-delay data were also collected for flagger control on the first day of the lane closure at Site 3. These data were not available from Sites 1 and 2, which were only one-day operations. However, data collection personnel at Site 1 (average daily traffic of 600) noted that all vehicles approaching the work zone during the time of the portable-signal study were isolated arrivals. It was assumed that flaggers would have allowed these vehicles to pass through the work zone without stopping, because they were the only vehicles present at that particular time. Consequently, averaged stopped delay per vehicle would have been negligible had flaggers been the method of traffic control. Unfortunately, a similar estimation was not possible at Site 2, because of the greater traffic volumes and longer work zone. Nevertheless, it was possible to compare vehicle stopped delay for flagger-controlled and signal-controlled operation at Sites 1 and 3.

STUDY RESULTS

Motorist Delay

One of the advantages to using flaggers is that they are responsive to random vehicle arrivals and gaps in the traffic stream, and can assign traffic movements through the work zone so as to minimize vehicle stops and delays. Fixed-time signals do not react to isolated random vehicle arrivals. Rather, motorist delay under signal control is a function of the timing parameters (cycle length, green phase time, etc.). Consequently, motorist delay should increase at a work zone when fixed-time portable signals are used in place of flaggers. At Site 1, which had low traffic demand, this was found to be the case. Table 2 shows that average stopped delay per vehicle was higher at Site 1 when traffic signals were used.

However, flaggers were not found to have as distinct an advantage over fixed-time signals when traffic demands were greater. As Table 2 shows, average stopped delay at Site 3 was nearly identical for both flagger and signal control. This site was a longer work zone than Site 1 and had dramatically higher traffic demand. Flaggers at Site 3 could not allow vehicles to pass through the work zone as they arrived (as could have been done at Site 1), but instead had to methodically assign traffic movement to one direction and then to the other. In effect, flaggers duplicated the operation of the fixed-time signals. Consequently, average stopped delay per vehicle was very similar for the two types of traffic control. These results indicate that at higher traffic volumes, fixed-time signals at a work-zone lane closure can provide a level of service to drivers comparable with that provided by flaggers. However, when volumes are low, signals may provide a poorer level of service than that attainable with flagger control.

TABLE 2 COMPARISON OF STOPPED DELAY: FLAGGER CONTROL VERSUS FIXED-TIME SIGNAL CONTROL

Site	Hourly Volume	Average Stopped Delay (sec/vehicle)			Added Stopped Delay (vehicle hr/hr)
		Flagger	Signal	Increase	
1	50^a	0^b	24	24	0.3
3	750^c	36	38	2	0.4

NOTE: Site 2 was not used in the comparison of stopped delays because such data were not available (and could not be reasonably estimated) for flagger control.
[a] Approach volume-to-capacity ratio (v/c) = 0.13.
[b] Estimated from observed traffic arrivals. No vehicles would have been forced to stop at this location had flaggers been used.
[c] v/c = 0.9.

Although the quality of service provided to drivers is an important factor to be considered, it is probably more important to examine the impacts of signal control from an economic standpoint. Portable signal systems are designed to be simple and easy to operate, so they require little additional setup time over that necessary to close the travel lane to traffic. Consequently, the primary operating cost associated with using portable signals is the amount of additional delay that it causes drivers approaching the work zone. Additional motorist delay per hour generated by the portable traffic signals above that incurred (or that would have been incurred) under flagger control is shown in the last column of Table 2. The values for both sites are nearly identical, and amount to less than 0.5 vehicle-hr of additional stopped delay per hour. The large increase in average delay at Site 1 affected only a small number of motorists, whereas the large number of drivers at Site 3 were affected by only a small increase in delay.

The low cost of additional motorist delay at the two study sites was more than offset by the savings in flagger labor costs. As Table 3 shows, fixed-time portable traffic signals provided significant cost savings over the use of flaggers. Computed savings at Sites 1 and 3 amounted to $9 and $14 per hour, respectively.

TABLE 3 SUMMARY OF PORTABLE SIGNAL COSTS AND BENEFITS

Site	Cost of Additional Motorist Delay ($/hr)[a]	Savings in Labor Costs ($/hr)[b]	Savings Achieved by Portable Signals ($/hr)
1	3.12	12.00	8.88
3	4.16	18.00	13.84

[a]Based on recent estimates of value of travel time = $10.40/vehicle-hr *(2)*.
[b]Based on typical wages and benefits of approximately $6/hr for Maintenance Technician I working for the Texas State Department of Highways and Public Transportation.

The portable signals examined in this study were reported to cost approximately $8,000 per pair. Using the previous conservative estimates of flagger labor cost savings, the signals would pay for themselves after 1,600 hr of service. Although these comparisons do not include any signal maintenance costs, the system still appears to have been a cost-effective alternative to flagger control at the sites studied.

Driver Noncompliance with Traffic Signals

One of the major concerns surrounding the use of portable signals in work zones is with whether drivers will obey them. Failure of a driver to obey the signal could lead to a serious head-on collision with an oncoming vehicle within the work zone.

In the following results of the noncompliance data collected at each site, column 1 gives the total number of motorists observed approaching and passing through the work zone, and column 2 gives the number of those vehicles that entered the work zone while facing a red indication. Columns 1 and 2 were then used to generate column 3, the rate of observed noncompliance per 1,000 vehicles.

	Vehicles Approaching Work Zone		
Site	*Total No.*	*No. Running Red*	*No. Running Red/1,000*
1	43	0	0
2	400	2	5
3	500	2	4

Although the rates indicate that noncompliance was not a major problem, the results show that a few vehicles were observed to enter the work zones on the red. These vehicles were stopped by research or work personnel, or both, before they had traveled very far into the site, so no accidents or major conflicts occurred. However, the potential for mishap was obviously present in these instances.

Although not shown, two different types of violations occurred at Sites 2 and 3. The first involved vehicles that initially came to a stop, but then entered the work zone while the light was still red. It appeared that the drivers of the vehicles saw the signals, but then chose to proceed through the work zone on the red even though they could not see completely through the work zone. (As stated previously, at none of the sites was there visibility from one end of the work zone to the other.) This type of noncompliance indicates that some drivers may question the validity of portable signals. It may be possible to improve signal validity by putting out a temporary stop line 50 to 60 ft in advance of the signal, as shown in Figure 1. The stop line identifies where drivers should stop and reinforces the need to stop. Also, a supplemental temporary Stop Here on Red sign (R10-6) *(1)* may be erected next to the bar to further enforce the need for stopping and add validity to the presence of the signals.

The other type of violation occurring at Sites 2 and 3 involved vehicles that ran the red light and entered the work zone without stopping, which suggests that they never saw the signals. Unfortunately, it may be quite difficult to reduce or eliminate these types of incidents. It was suggested that the manufacturer of the portable signals increase the wattage of the lamp heads in order to make them more visible in daylight. Other attention-getting devices may be available to increase the conspicuity and attention-getting capability of the signals. However, identification and experimentation with these types of devices was beyond the scope of this study.

SUMMARY

The results have been presented of field studies examining the use of fixed-time portable traffic signals instead of flaggers at work zones requiring alternating one-way traffic control. On the basis of these limited studies, fixed-time signals appear to be a suitable alternative to the use of flaggers for alternating one-way traffic through a work zone. Significant savings in flagger labor costs can be realized with what appears to be a minimum of additional delay costs to motorists. However, the trade-offs between the potentials for reduced flagger accidents and increased vehicle accidents in work zones cannot be accurately estimated at this time. Some supplemental signs and devices have been suggested to reduce the occurrence of motorist noncompliance with the signals, but the devices have not been tested under field conditions.

As the use of portable signals increases and drivers become more accustomed to their presence in work zones, it would be expected that motorist compliance with them would improve. The limited studies documented here can only serve as a starting point to determining the effects of portable signals at work-zone lane closures. Continued research and experience with portable signals will be needed before the full benefits and costs associated with their use are known.

ACKNOWLEDGMENT

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REFERENCES

1. *Manual on Uniform Traffic Control Devices.* FHWA, U.S. Department of Transportation, 1978.
2. M. Chui and W. F. McFarland. *The Value of Travel Time: New Estimates Developed Using a Speed-Choice Model.* Report FHWA/TX-86/33+396-2F. Texas Transportation Institute, College Station, Tex., May 1986.

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