Evaluation of Advanced Surveying Technology for Accident Investigation

KENNETH R. AGENT, JOHN A. DEACON, JERRY G. PIGMAN, AND NIKIFOROS STAMATIADIS

The objective was to evaluate the use of advanced technology for the investigation of traffic accidents. Substantial time and manpower are sometimes required to properly investigate serious vehicular crashes and document on-scene data. An alternative to the traditional coordinate method for on-scene data collection is the use of electronic total stations. This is a form of digital surveying equipment that can be used to obtain detailed measurements, with the option of plotting the stored data by computer. The study compared the use of advanced surveying technology with the traditional coordinate method. Detailed estimates of data collection activity were documented for a selected accident sample, and accident clearance times were documented for a much larger sample. The analysis indicated that the investigation of traffic accidents by using total-station surveys provides a substantial improvement over the traditional coordinate procedure. The number of measurements obtained at an accident scene increased by a factor of approximately 2 when the total-station equipment was used. The time to collect the data decreased by about 33 percent, and the man-hours decreased by about one-half. Computer plotting by the total-station procedure also resulted in a significant time savings. Decreased data collection time resulted in significant time and fuel savings to the driving public. Recommendations were made for continued use of the equipment and the purchase of more equipment when funds become available. It addition, policies for using the total-station equipment at all fatal and serious injury traffic accidents are recommended.

Serious traffic accidents traditionally require substantial time for on-scene investigation and, as a result, often seriously inconvenience and delay traffic. Electronic surveying equipment now provides an alternative to the traditional coordinate procedure. Instead of using a tape measure, digital surveying equipment is used to obtain detailed measurements, and the accident diagram is plotted by computer by using data automatically stored during the measurement process.

The study described here explores the use of advanced technology for obtaining and processing accident data. Potential benefits include decreasing the data collection time, increasing the accuracy of the data, reducing risks to investigators, and making analysis of the data easier. Moreover, decreasing the amount of time required to collect on-scene data reduces traffic delays, decreases fuel consumption and the emission of pollutants, and reduces the potential for secondary accidents. However, this could mean increased equipment costs, increased training requirements, weather-related delays, and limited availability of equipment and trained operators.

The traditional method of collecting field data at a traffic accident site is based on a coordinate procedure (*1*). Distance measurements are made with either a measuring tape or a wheel. By this procedure a reference line and a reference point on that line are identified, and measurements are made relative to those references. Two measurements are required to locate a spot. One is the distance (usually the shortest) from the spot to the reference line. The second is the distance from that location on the reference line to the reference point. In addition to distance, direction must be specified. The coordinate method typically requires a minimum of two people plus those necessary for traffic control. Although it can produce accurate results, a substantial amount of time is required to collect the data and manually prepare a scale drawing, especially if a large number of points is necessary.

An alternative to the coordinate procedure is computerized surveying equipment, or electronic total stations. The total station not only replaces the tapes and measuring wheels but also stores data digitally rather than in the traditional field book. The data are subsequently downloaded into a computer to produce detailed scale maps. This provides the possibility of a procedure that is more efficient than preparing drawings manually from the data collected by the coordinate method.

The objective of the present study was to evaluate the use of advanced surveying technology for the investigation of traffic accidents on the basis of the experiences of the Lexington–Fayette Urban County Police (LFUCP) and the Kentucky State Police (KSP). The only other known formal evaluation of total stations was performed in the state of Washington (*2*). The study compared the investigation of traffic accidents by using surveying technology with that by using the traditional coordinate method. Measures of merit included, among others, the time required for data collection, the amount of data collected, and the time required to prepare the accident diagram. The cost-effectiveness of total-station surveys was also assessed.

EQUIPMENT

The total station is a combination of an electronic distance meter, which uses infrared light to measure distance, and a digital theodolite. The instrument transmits an invisible infrared beam that reflects back from a prism placed at the measurement spot. The infrared light replaces the typical measuring tape or wheel. The theodolite measures the horizontal angle from the baseline and the vertical angle from the horizon. The investigator places the total station at a position where most or all of the measurement locations can be observed. The prism is mounted on a tall rod so that measurements can be taken over objects such as passing traffic.

The total station calculates three-dimensional coordinates for each point relative to a reference point. Distance, horizontal angle,

Kentucky Transportation Center, College of Engineering, University of Kentucky, Lexington, Ky. 40506-0281.

and vertical angle are obtained. A code is entered for each datum point, and the data are stored for later downloading into a computer. The computer interprets the field codes and prepares a map of the scene. Either a rough drawing made by using the data directly from the total station or a more detailed drawing made by using a drafting program can be obtained.

This type of equipment is available from several manufacturers. The Sokkia surveying system was used in this evaluation. A list of the necessary equipment and their costs is given in Table 1. The equipment included the surveying system as well as the computer software and plotters. Five total-station units were purchased: two units were used by LFUCP and three were used by KSP. The three KSP units were placed in separate posts located across the state. The total cost of the equipment in 1993 was approximately $100,000, about $20,000 per unit. Since this cost included plotters and other office equipment, the cost of purchasing only the surveying equipment was considerably less. A 1-week training class entitled Incident Management with Accident Reconstruction/Mapping Technology was included in the total cost.

DATA

Although the total-station procedure has many potential advantages, the one of greatest interest was the reduction in the amount of time necessary for on-scene data collection. Estimates of data collection time (by both coordinate and total-station procedures) were documented for a selected accident sample by using accident investigation work logs. In addition, accident clearance times were documented for a much larger sample of accidents to determine the extent to which total-station procedures would likely prove advantageous.

Field Investigation Information

An accident investigation work log was completed by both KSP and LFUCP after each accident investigation with the total-station equipment (Figure 1). For each accident general information relating to the road type, type of accident, numbers and types of vehicles involved, and accident severity was entered into the work log. Also entered into the log was information concerning the data collection process including the time to collect the data, the number of measurements, the number of officers and man-hours required to collect the data, and the road closure time. Finally, the time to prepare the accident diagram was recorded.

KSP investigated 32 accidents using total-station surveys. For seven of these data collection was duplicated by the coordinate procedure, and an accident investigation work log was filed for each of these coordinate surveys as well. LFUCP investigated 16 accidents using total-station surveys. Also, a review of LFUCP accident records of past investigations done by the coordinate procedure was performed.

Accident Scene Clearance Times

The time required for on-scene data collection was among the items reported on the accident investigation work log. Because the sample of accidents for which work logs were prepared was relatively small, independent estimates of the time to clear the accident scene were desired. Fortunately, the uniform accident report identifies both the time that the police arrive at an accident scene and the time that the scene is cleared, that is, the time that all traffic lanes are opened and traffic movement is unrestricted. It should be noted that the time that the scene is cleared does not necessarily coincide with termination of data collection activities. In fact, data collection typically concludes before the scene is officially cleared. However, these two times, the data collection time and the accident clearance time, helped to gauge the potential effects of any improvements associated with the use of total-station equipment.

By using a computerized file of traffic accidents for the time period of 1991 through 1993, summaries were obtained for both Lexington–Fayette Urban County and statewide. Average clearance times were obtained as a function of variables such as accident severity, highway type, vehicle type, number of vehicles, and type

TABLE 1 Total-Station Equipment and Cost

	Number		Cost[a]	
Equipment	KSP	LFUCP	KSP	LFUCP
Leitz Total Station and Supplies	3	2	$31,052	$20,702
Notebook Computer and Software	4	1	10,000	2,200
Various Surveying Supplies			6,370	4,140
Hewlett Packard Plotters	1	1	5,840	5,840
Digitizer Boards	1	1	1,676	1,676
Digitizer Table Stands	1	1	453	453
Computer Modem	1		1,163	
Map Software	4		3,702	
Autosketch Computer Program	2		350	
Laser Printer	1		725	
Computer Equipment	1	1	1,525	1,525
Printing Supplies			554	734
Total			$62,685	$37,995

[a]Purchase price in 1993.

ACCIDENT INVESTIGATION WORK LOG

DATE ________

LOCATION ____

CASE NUMBER ____________

GENERAL INFORMATION:

ROAD TYPE: Interstate ____ Two-Lane ____ Four-Lane ____
TYPE OF ACCIDENT: Collision ____ Non-Collision ____
NUMBER OF VEHICLES: ____
TYPE OF VEHICLE: Vehicle 1 __________
Vehicle 2 __________
Vehicle 3 __________
Vehicle 4 __________
SEVERITY: Property-damage-only ____ Injury ____ Fatal ____
ALCOHOL INVOLVED: Yes ____ No ____

FIELD INVESTIGATION:

TIME TO COLLECT MEASUREMENTS ______
TOTAL NUMBER OF MEASUREMENTS ______
ROADWAY-RELATED MEASUREMENTS _____
ACCIDENT-RELATED MEASUREMENTS _____
NUMBER OF OFFICERS COLLECTING DATA _____
MAN-HOURS TO TAKE MEASUREMENTS _____
TOTAL ROAD CLOSURE TIME _____
COMMENTS ________________________________
____
____

ACCIDENT DIAGRAM:

TIME TO PREPARE DIAGRAM _____
MAN-HOURS TO PREPARE DIAGRAM _____
COMMENTS ________________________________
____
____

FIGURE 1 Work log.

of accident. The number of accidents requiring excessive clearance times indicates the potential for the effective use of total-station equipment.

RESULTS

Field Investigation

In a 1-year time period the total-station procedure was used a total of 32 times by KSP and 16 times by LFUCP. The benefits of using the total-station procedure compared with the coordinate procedure are summarized in Table 2. The mean number of measurements per accident was approximately doubled for total-station surveys, whereas the time and man-hours required to collect the data decreased substantially. Data collection time, for example, decreased from an average of more than 3 hr to about 2 hr. The mean number of measurements per man-hour increased dramatically when the total-station equipment was used. Finally, KSP (but not LFUCP) reported a slight reduction in the average number of on-scene investigators with total-station surveys. However, for either coordinate or total-station surveys, the practical minimum number of investigators is two.

By using past LFUCP accident reports, additional data, summarized in Table 2, were available for 124 accidents in which the coordinate procedure was used. The times given for the coordinate method were the clearance times obtained from the LFUCP accident reports. The number of measurements was also recorded on the police report. A comparison showed that the measurements per man-hour increased by a factor of slightly more than 3 by the total-station procedure compared with those by the coordinate procedure.

At seven locations where KSP investigated an accident, both coordinate and total-station surveys were used. In these situations the scene was first measured by the coordinate procedure; measurements were repeated later with the total-station equipment. At these sites 3 times as many measurements were taken by the total-station procedure in approximately one-half the time.

TABLE 2 Comparison of Coordinate and Total-Station Data Collection Methods

	KSP		LFUCP	
Coordinate Method				
Number of Accidents	7[a]		124[b]	
Mean Number of Measurements	36.1	(22.1-50.2)[c]	47.9	(41.9-53.9)
Mean Data Collection Time (Min)	214	(153-275)	188	(175-201)
Mean Number of Man Hours	11.9	(7.9-15.8)	10.8	(9.5-12.0)
Mean Measurements per Man Hour	3.3	(2.1-4.5)	5.2	(4.6-5.8)
Mean Number of Investigators	3.3	(2.8-3.7)	3.3	(3.1-3.5)
Total Station Method				
Number of Accidents	32		16	
Mean Number of Measurements	83.6	(71.0-96.2)	96.9	(74.8-118.9)
Mean Data Collection Time (Min)	111	(89-134)	124	(93-154)
Mean Number of Man Hours	4.5	(3.6-5.4)	6.7	(5.0-8.5)
Mean Measurements per Man Hour	21.8	(18.2-25.4)	17.7	(12.1-23.2)
Mean Number of Investigators	2.5	(2.2-2.7)	3.2	(2.9-3.6)

[a]The KSP collected total-station data at the seven locations where data were collected using the coordinate method. At these seven locations, an average of 109 measurements were collected in an average of 4.1 man hours giving an average of 26.6 measurements per man hour. Data collection times and number of investigators averaged 100 minutes and 2.4 people, respectively.
[b]These data are based on information given on the police accident report.
[c]Numbers in parentheses represent the 95-percent confidence interval for the mean.

The differences in the means between coordinate and total-station surveys in Table 2 were analyzed by Student's *t*-test to ascertain if they were statistically significant at a significance level of 5 percent. Separate analyses were conducted for the KSP data (both 7 by 32 and 7 by 7) and the LFUCP data (124 by 16). For the 7-by-7 KSP data, paired *t*-tests were also performed. With one exception, that is, the mean number of investigators used by LFUCP, all differences between total-station and coordinate surveys were found to be statistically significant at a 5 percent or better significance level.

Factors that might affect data collection at an accident site, including accident severity, road type, and numbers and types of vehicles, were also summarized. The results of this summary are given in Table 3. The data for coordinate surveys were limited to those obtained by LFUCP because of the rather large sample of data. Data from both KSP and LFUCP were used to examine the total-station procedure.

The average accident clearance times for the coordinate surveys were largest for Interstate highways, for accidents involving more than three vehicles, and for accidents involving trucks. Also, the average time to clear fatal accident sites was substantially longer than that to clear injury accident sites.

Similar trends for road type, number of vehicles, and vehicle type were found for total-station surveys, but the man-hours required to collect the data were dramatically reduced. The data show that total-station equipment was used primarily in the investigation of fatal accidents. The time to investigate a small number of property-damage-only accidents was substantially less than that to investigate injury or fatal accidents.

Discussions were held with officers experienced with total-station surveys to obtain their opinions and observations. All comments were positive: the consensus was that total stations allowed more accurate and more detailed measurements in a shorter period of time. Although a short training period was required, total stations were not found to be difficult to operate. One drawback was that total stations could not be used during certain weather conditions. However, in these instances points could often be marked with paint at the time of the accident, and measurements could be delayed until the weather was more favorable.

Accident Diagram

Measurements taken at the accident scene are used to prepare an accident diagram. Although only a rough diagram of the accident scene is prepared in many cases, it is sometimes necessary or desirable to prepare a scaled accident diagram. A limited amount of information was available from the police agencies to compare the time required to prepare a scaled drawing of the accident scene by using data from either the coordinate or the surveying procedures.

This information showed that the time savings associated with preparing the accident diagram by the total-station procedure compared with that by the coordinate procedure was of a magnitude similar to that for data collection. Discussions with the police officers indicated that the time to prepare detailed diagrams was decreased by at least 50 percent by the total-station procedure. The total-station procedure also provided a more automated method with substantially more datum points. This resulted in the preparation of a more accurate diagram in a shorter time period.

Benefit–Cost Analysis

A comparison was made between the cost of purchasing total-station equipment and the primary benefit thought to be associated

TABLE 3 Variables Affecting Data Collection

	Number of Accidents[a]		Average Number of Measurements		Average Time (Min)		Average Man-Hours	
Variable	Coord[b]	TStation	Coord	TStation	Coord	TStation	Coord	TStation
Road Type								
Two-Lane	69	30	48	85	190	110	10.4	4.5
Four-Lane	42	11	45	113	180	130	9.9	7.1
Interstate	8	6	72	65	270	145	21.0	6.8
Number of Vehicles								
One	66	7	40	87	175	95	8.9	5.0
Two	46	29	55	87	200	120	12.0	5.2
Three	7	8	68	85	220	110	13.8	4.3
Over Three	5	3	65	125	245	160	20.7	9.1
Vehicle Type								
Cars Only	117	38	46	88	180	110	9.9	5.1
Trucks Involved	7	8	78	85	295	138	24.8	5.8
Severity								
Fatality	62	32	54	94	205	125	12.8	5.5
Injury	60	8	41	100	170	115	8.6	6.4
Property Damage		7		57		80		3.2
All	124	38	48	88	185	120	10.8	5.2

[a]Inconsistent subtotals indicate missing information.
[b]Excludes two property-damage-only accidents.

with its use. Although the police agency benefits by the reduction in man-hours required to investigate a traffic accident and prepare an accident diagram, the major benefits are realized by motorists in terms of reduced delay (time cost) and fuel consumption (fuel cost). To obtain a first-order approximation of benefits, therefore, the focus was placed on travel-time delay and fuel savings.

A review of the literature was conducted to determine the appropriate costs of time and fuel. Time costs ranging from $6.25 to $7.00 for each vehicle hour of delay have been reported (*2–4*). Fuel cost was estimated by assuming that each vehicle hour of delay uses about 1.1 gallons of fuel (*4*), which costs about $1.00 per gallon. A cost of $8.00 per vehicle hour of delay was therefore used in the analysis as the estimate of the combined cost of time and fuel.

The cost of the field equipment necessary for a total-station survey was determined to be about $15,000 per unit. An additional cost of about $10,000 would be necessary for office equipment, but the office equipment would generally support multiple field units. Nevertheless, given a maximum cost of $25,000 to implement a total-station procedure and time and fuel savings valued at $8.00 per vehicle hour of delay saved, a reduction of about 3,125 vehicle hours in delay would be necessary to offset the original equipment costs.

The potential vehicle hours saved must be estimated to compute the associated delay and fuel savings. Kentucky experience, summarized earlier, suggests that the time required to investigate severe accidents was reduced by about 60 min when using total-station surveys. The typical investigation took about 180 min by the coordinate method, compared with about 120 min by the total-station procedure.

Various scenarios were used to estimate the reduction in vehicle delay and fuel costs associated with a reduction in data collection time from 180 to 120 min. During some accident investigations the road is blocked for a portion of the time, whereas in other cases traffic flow continues but at a slower rate and speed. In all cases the travel time is increased during the accident investigation. The analysis assumed either a complete blockage, a partial blockage, or an intermittent blockage. A graphical description of the assumed departures during the investigation is provided in Figure 2. The stopped delay (in vehicle hours) is represented by the shaded areas in Figure 2.

For the complete blockage scenario the road was assumed to be blocked for the entire data collection time. For the partial blockage scenario traffic was assumed to continue to flow during the investigation, but at a reduced rate. For the intermittent blockage scenario traffic was assumed to be blocked for a portion of the blockage time and was allowed to flow at a reduced rate during the remainder of the blockage time.

Estimates were made for a four-lane freeway (one direction of travel) and for a two-lane roadway. Regardless of the scenario, it was assumed that the departure rate following completion of the accident investigation was 3,600 vehicles per hour (v/hr) in one direction for the freeway and 1,800 v/hr in both directions for the two-lane, two-way roadway.

Only stopped time delay was considered. The additional delay associated with stopping and starting and with any reduced speed in approaching the accident zone and departure from the queue was not included. Moreover, the calculations did not differentiate between the obstructed flow rates by the coordinate and total-station procedures. Since the total-station procedure is less disruptive to

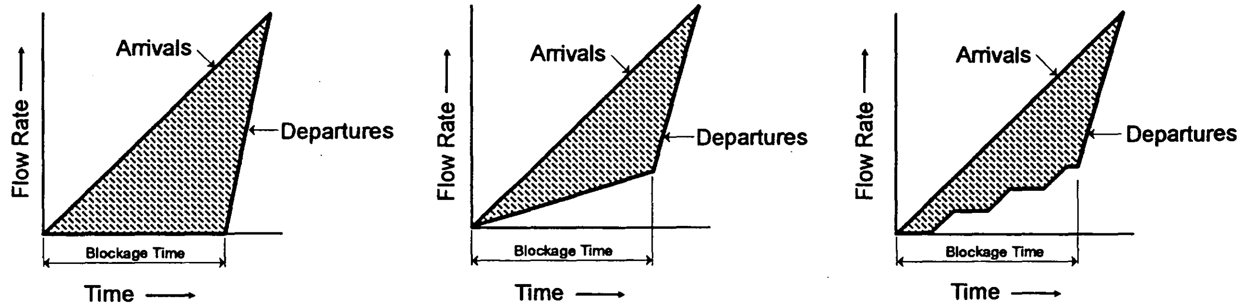

FIGURE 2 Assumed departures for complete (*left*), partial (*middle*), or intermittent (*right*) blockages.

traffic, an additional savings in delay would likely be gained from this factor. Thus, the benefits attributed here to total-station surveys are considered to be conservative.

The two-lane scenario involved the complete closure of one lane, with the second lane being used to accommodate one-way travel in alternating directions. The assumption was made that 3 min was alternately allocated to each direction, followed by a 30-sec dead interval. This yielded a 7-min cycle time for use of the open lane.

Accidents occur on all types of roads under a variety of traffic volume. The average annual daily traffic (ADT) on state-maintained, rural, two-lane roads in Kentucky is about 1,500 vehicles per day (vpd), compared with about 6,900 vpd in urban areas (*5*). The average ADT on four-lane divided (non-Interstate or parkway) roadways varies from 8,800 vpd in rural areas to 21,500 vpd in urban areas. Average ADTs on rural Interstates are 21,400 vpd, compared with 53,700 vpd on urban Interstates. On the basis of these average ADTs, hourly volumes on the majority of Kentucky roadways are typically less than 1,000 v/hr on two-lane highways and 2,000 v/hr (one direction) on four-lane freeways. These hourly maxima defined the upper limits of the hourly volumes investigated here.

The vehicle hours of delay associated with an accident investigation can be estimated by using the length of a typical investigation for both the coordinate and the total-station procedures, the type of traffic interruption created by the investigation, and the traffic volume during the investigation period. The macroscopic analysis assumed that flow was deterministic and at steady state. Results of the analysis, presented in terms of the savings in stopped-time delay by reducing on-scene data collection time from 180 to 120 min, are summarized in Figures 3 and 4.

The freeway analysis, presented in Figure 3, shows the reduction in vehicle hours of delay assuming complete blockage as well as partial blockage (obstructed one-way flow rates of 500, 1,000, and 1,500 v/hr). For example, if an approach flow rate of 1,000 v/hr is reduced to 500 v/hr during the investigation, approximately 1,500 vehicle hours of delay can be eliminated by reducing the investigation time from 180 to 120 min.

The two-lane, two-way road analysis, presented in Figure 4, examines complete blockage as well as intermittent blockage (one-way flow rates of 250, 500, and 750 v/hr). For example, if an approach two-way flow rate of 500 v/hr is reduced to an intermittent, obstructed one-way flow rate of 250 v/hr during the investigation, a savings of about 800 vehicle hours of delay can be realized.

By using time and fuel costs of $8.00 per vehicle hour of delay and the reduction in stopped delay shown in Figures 3 and 4, the estimated dollar savings from use of the total-station procedure can be estimated. When this savings is compared with the cost of $25,000 for total-station equipment and training, the breakeven point requires a savings of 3,125 hours of delay.

During high-volume periods the savings associated with total-station surveys pays for the equipment almost immediately: only one or two accident investigations are required. Even for low-volume conditions, the savings would pay for the equipment after as few as about 10 accident investigations. Given the potential use of the equipment, these savings can likely be realized in no more than a few months and possibly within a few weeks (depending on the types and locations of accidents investigated).

This analysis understates the dollar benefits of the total-station procedure because it neglects benefits resulting from reduced police manpower requirements and from improved accuracy in documenting and reconstructing traffic accidents. Moreover, traveler benefits can be quite substantial even with time savings considerably less than the 1 hr that has been assumed, particularly when traffic volumes are large. For example, traveler benefits exceed total-station purchase costs after only three accident investigations that reduce 60-min blockages by 5 min on four-lane freeways carrying approximately 3,000 v/hr in the blocked direction.

Accident Clearance Times

The time necessary to clear an accident scene can be determined by using information given on the police accident report and recorded in the statewide accident data base. An analysis was performed to determine the averages and distributions of clearance times in Lexington–Fayette Urban County as well as statewide during the period from 1991 through 1993. Average clearance times were also compared with several contributing factors.

The number of accidents with long clearance times gives an indication of the potential frequency of highly productive applications of the survey equipment. However, the critical factor affecting clearance times is not always the data collection time. Cleaning up spills and removing vehicles are examples of other reasons for long clearance times. In those instances reducing the investigation time is not expected to significantly reduce the clearance time.

The average clearance time for Lexington–Fayette Urban County accidents was 70 min. This compares with an average of 51 min statewide. The distribution of clearance times is given in Table 4. In Lexington–Fayette Urban County almost one-half of the clearance times were 15 min or less and approximately two-thirds were 30 min or less. Statewide statistics also show that about two-thirds of the clearance times were 30 min or less.

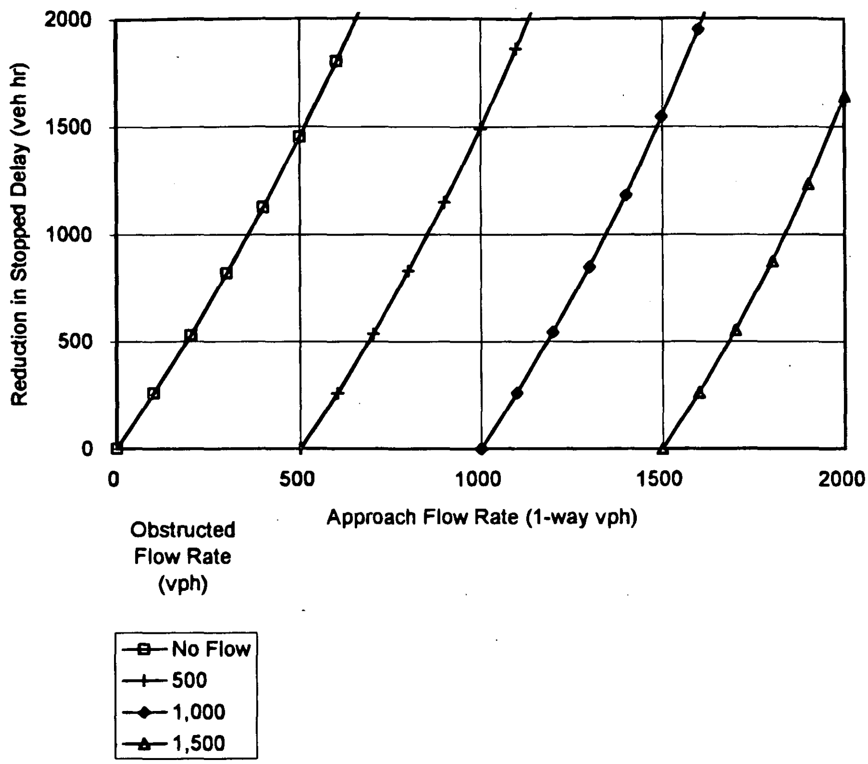

FIGURE 3 Reduction in stopped delay on a freeway associated with use of total-station equipment (freeway obstruction: 2-hr instead of 3-hr blockage).

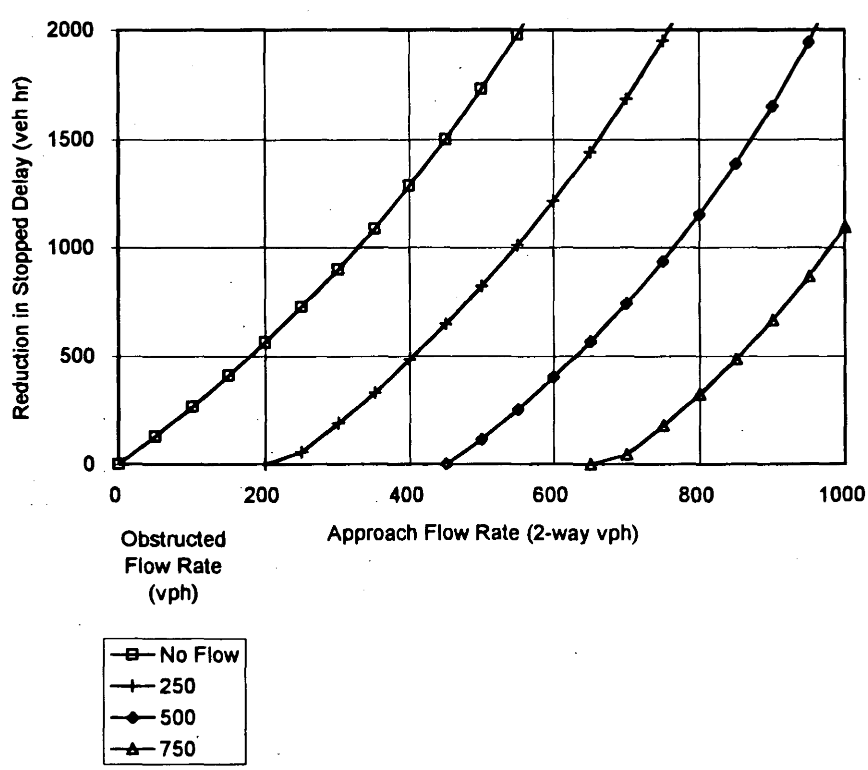

FIGURE 4 Reduction in stopped delay on a two-lane highway associated with use of total-station equipment (two-lane, two-way, road obstruction: 2-hr instead 3-hr blockage).

TABLE 4 Distribution of Accident Clearance Times (1991–1993)

Time Range (Min)	Percent in Time Range	
	Lexington-Fayette Urban County	Statewide
15 or less	46.3	35.2
16 - 30	21.2	32.4
31 - 45	13.3	15.5
46 - 60	6.2	6.6
61 - 90	3.5	4.2
91 - 120	0.9	1.2
121 - 180	0.8	0.8
181 - 240	0.5	0.4
241 - 300	0.4	0.2
Over 300	7.0	3.5

About 8 percent of all accidents in Lexington–Fayette Urban County had clearance times longer than 180 min, compared with about 4 percent statewide. These are typical of the types of accidents for which total-station equipment can be most beneficial. In 1 year this represents about 950 accidents in Lexington–Fayette Urban County and about 5,500 accidents statewide. Thus the number of accidents for which total-station equipment could likely be used in a highly effective manner is substantial.

Analysis of each of Kentucky's 120 counties found a large range in average accident clearance times, with 11 counties having average times longer than 120 min and 3 counties with averages longer than 180 min; 5 counties had average times shorter than 30 min. Despite large variations among the counties, a significant number of long-clearance-time accidents occur in almost all counties. During the 3-year analysis period, for example, all counties experienced at least 10 accidents for which the clearance time was 120 min or longer (Figure 5). Thirty counties experienced at least 100 accidents for which the clearance time was much longer (300 min or more). Although not all of these long-clearance-time accidents occur when traffic is heavy, the potential for cost-effective use of total-station equipment during accident investigations appears to be distributed rather widely throughout the state.

As indicated in Table 5, clearance times are related to several accident characteristics. It appears that accidents for which the savings resulting from total-station surveys are likely to be greatest include fatal accidents, nighttime accidents, truck accidents, single-vehicle accidents, and Interstate or parkway accidents. Road user savings, such as reduced delays and reduced fuel consumption, are related directly to traffic volumes, and as a result, high-volume roads and streets are priority locations for expedited accident investigations.

CONSISTENCY OF FINDINGS

Researchers in the state of Washington (*2*) have documented an investigation of the benefits of total-station surveys for accident investigation similar to the present one. One facet of their investi-

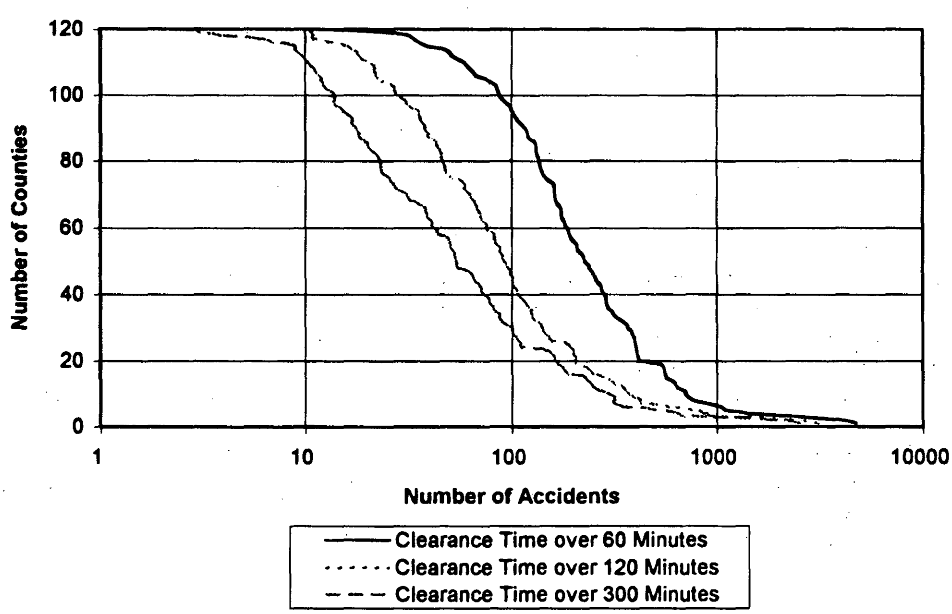

FIGURE 5 Cumulative distribution of county accidents by clearance time.

TABLE 5 Influence of Accident Characteristics on Clearance Time

		Average Clearance Time (Min)	
Variable	Category	Lexington-Fayette Urban County	Statewide
Severity	Fatal	188	120
	Injury	54	57
	Property Damage Only	69	47
Time of Day	Midnight - 5:59 am	117	91
	6:00 am - 11:59 am	78	59
	Noon - 5:59 pm	59	42
	6:00 pm - 11:59 pm	52	42
Highway Type	Interstate/Parkway	91	77
	Other State Maintained	56	50
	Local/County	72	45
Light	Daylight	62	47
	Dawn/Dusk	58	52
	Darkness	73	58
Vehicle Type	Truck Involved	79	70
	No Truck Involved	65	48
Number Vehicles	One	83	74
	Two	65	42
	Three	44	41
	Four or More	48	53
Type Accident	Other Vehicle	63	42
	Fixed Object	87	76
	Non-Collision	93	83
	Pedestrian or Bicycle	66	50
Location	Intersection	53	37
	Non-intersection	66	57
Land Use	Rural	79	75
	Business	55	37
	Residential	60	43
	Limited Access	76	68

gation was a detailed examination of three accident locations, all on two-lane highways, for which data were collected by both the coordinate method and the total-station method. The total-station surveys produced an average of about 70 percent more measurements per hour and reduced the average investigation time from 130 to 60 min. Table 6 compares the Washington and Kentucky summaries. Although the differences between states were large, the total-station surveys were always superior: they produced at least 21 more measurements each hour and reduced data collection times by a minimum of 60 min.

A second facet of the Washington investigation was a before-and-after study of clearance times of urban freeway accidents in Seattle. In the before period 20 accidents had been investigated by using coordinate surveys. In the after period 15 similar accidents had been investigated by using total-station surveys. As a result of the use of total stations the average clearance time was reduced from 182 to 131 min, a statistically significant average time savings of 51 min. Although similar before-and-after data are not available for Kentucky, the 51-min savings is compatible with estimates obtained from other types of comparisons in Kentucky.

A third major aspect of the Washington investigation was a benefit–cost analysis of the investigation of a single, peak-period accident. Peak-period volumes on the five-lane facility were approximately 9,090 v/hr. It was assumed that two lanes were blocked and that a total-station survey reduced the blockage time from 182 to 131 min. Under these conditions the savings attributed to the use of the total station were estimated to include 7,000 vehicle hours of delay. The researchers concluded that the approximately $15,000 cost for the total-station equipment would be more than recovered after just one use in investigating a major, peak-period accident on an urban freeway. Analyses in Kentucky not only support this conclusion but also suggest a favorable benefit–cost ratio after total-station equipment is used to investigate just a few severe accidents on less heavily trafficked facilities.

Finally, according to estimates by the Washington State Patrol, the automated drafting used with the total-station surveys reduced

TABLE 6 Comparison of Kentucky and Washington Data

	Washington	KSP	LFUCP
Measurements per Hour			
Coordinate Method	28.8	10.0	15.5
Total Station Method	49.8	44.2	46.1
Percent Increase	73	342	197
Average Investigation Time (Min)			
Coordinate Method	130	216	186
Total Station Method	60	114	126
Percent Decrease	54	50	32

the time for preparing drawings of each accident site from about 8 hr to about 2 hr. Investigators in Kentucky reported a more modest improvement of about 50 percent.

CONCLUSIONS

The analysis shows that the investigation of traffic accidents with total-station (survey) equipment provides a substantial improvement over investigation by the traditional coordinate procedure. The number of measurements obtained at an accident scene increased (by a factor of about 2) when total-station equipment was used. The time to collect the data decreased by about 33 percent, and the number of man-hours decreased by about one-half. The increase in the number of measurements results in a more accurate and detailed investigation and accident diagram. The use of computer plotting in the total-station procedure results in a significant time savings when a detailed accident diagram is needed.

More important, the decreased time required to collect field data results in significant time and fuel savings to the driving public. Estimates of the savings in delay demonstrated that the total-station equipment would result in savings that would pay for its cost after only a few investigations. This indicates that the use of this type of equipment for accident investigation is economically justified.

An analysis of clearance times at accident sites showed that there was potential for substantial use of total-station equipment throughout the state of Kentucky.

RECOMMENDATIONS

The analysis results in the recommendation that the use of total-station equipment be expanded as funds become available for equipment purchase. Specifically, each KSP post should have this equipment, as should other police departments with officers with advanced training in accident investigation. Proper training must be provided to ensure that the equipment is used properly. A policy should be established that use of the total-station equipment should be considered at all fatal and serious injury traffic accidents to ensure that optimum use is made of the equipment.

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