Research Report
KTC-94-18

EVALUATION OF ADVANCED SURVEYING TECHNOLOGY FOR ACCIDENT INVESTIGATION

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16. Abstract

The objective of this study was to evaluate the use of advanced surveying technology for the investigation of traffic accidents.

The analysis shows that the investigation of traffic accidents using total station (survey) equipment provides a substantial improvement over the traditional coordinate procedure. The number of measurements obtained at an accident scene increased (by a factor of about two) when the total station equipment was used while the time required to collect the measurements decreased by about 33 percent with the 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 than typically obtained with the coordinate procedure. The use of computer plotting in the total station procedure results in a significant time savings when a detailed accident diagram is needed.

It is recommended that the use of total station equipment be continued and expanded.

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INTRODUCTION

Serious traffic accidents require a substantial amount of time for on-scene investigation. Data collection and preparation of an accident diagram can require many man-hours to complete. While data collection is ongoing, traffic delays occur. An alternative to the traditional coordinate procedure is now available. Instead of using the standard tape measure, digital surveying equipment is used to obtain precise measurements, and the accident diagram is plotted by computer using data stored during the measurement process.

There is a need to evaluate this alternative method of obtaining and processing accident scene data. Potential benefits of this technology include decreasing the data collection time, increasing accuracy of the data, reducing risks to investigators, and making analysis of the data easier. Moreover, decreasing the amount of time required to collect the data reduces travel time, traffic delay, decreases fuel consumption and the emission of pollutants, and reduces the potential of secondary accidents. Potential disadvantages include increased equipment costs, increased training requirements, 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 using either a measuring tape or wheel. Using this procedure, a reference point and reference line are identified, and measurements are made relative to these references. Two measurements are required to locate a spot. One is the distance (usually the shortest) from a spot to the reference line, and the second is the distance from that location on the reference line to the reference point (which is on the reference line). The two measurements are usually at right angles to each other. In addition to distance, the direction must be specified. The coordinate method typically requires a minimum of two people plus those necessary for traffic control. While this procedure can produce accurate results, a substantial amount of time is required to collect the data and manually prepare a scale drawing. If a large number of points are necessary to prepare an accurate diagram, the data collection time can be significant.

An alternative to the coordinate procedure is to use computerized surveying equipment, or electronic total stations, and related software for data collection. This equipment replaces the tapes and measuring wheels used in the coordinate procedure by collecting and storing the data digitally rather than in the traditional field book. The collected data are subquently downloaded into a computer for plotting and scaled graphics display. This provides the possibility of a more accurate and efficient procedure compared to preparing manual drawings from the data collected using the coordinate method.

The objective of this study was to evaluate the use of advanced surveying technology for the investigation of traffic accidents. The only other known formal evaluation of the use of total stations was performed in the state of Washington (2). The surveying equipment evaluated as part of this study is being used by the Lexington-Fayette Urban County Government (LFUCG) Police and the Kentucky State Police (KSP). This study compared the investigation of traffic accidents using the surveying technology with the use of the traditional coordinate method. The time required to collect the data was analyzed as well as the amount of data collected. In addition, the time required to use the field measurements to prepare an accident diagram was investigated.

EQUIPMENT

The electronic 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 which reflects back from a prism placed at each measurement location. 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 instrument at a position where most or all of the measurement locations can be observed. In many cases only one placement is necessary. The prism is on an adjustable rod so that measurements can be taken over objects such as trucks and other passing traffic.

The total station calculates three dimensional coordinates for each point relative to a reference point. Distance, horizontal angle, and vertical angle are obtained. A code is entered for each data point. Codes selected were descriptive of the data they were representating and a series of data points were connected, using the codes, to plot the accident scene. The data are stored and then downloaded into a computer. The computer interprets the field codes and draws a map of the scene. Either a rough drawing using the data directly from the total station or a more detailed drawing using a drafting program can be obtained.

This type of equipment is available from several manufacturers. Due to its simplicity and reliability, the Sokkia surveying system was used in this evaluation. A list of the necessary equipment and its cost is given in Table 1. The equipment included the surveying system as well as the computer software and plotters necessary to present the data. Five total station units were purchased: two units were used by the LFUCG police in Lexington and three were used by the KSP. The three units used by the KSP were placed in three separate posts spread across the state (the Elizabethtown, Dry Ridge, and Richmond posts). The total cost of the equipment in 1993 was approximately $100,000. This cost would be about $20,000 per unit. Since this cost included the plotters, computers, and software, the cost of purchasing only the surveying equipment necessary to collect the data is considerably less.

Training was included in the total cost. A one-week class entitled "Incident Management with Accident Reconstruction/Mapping Technology (ARMT)" was given by the equipment vendor and manufacturer. The training was given by individuals who had experience using the equipment for the purpose of accident investigation. Personnel from the LFUCG police and KSP who were planning to use the equipment attended this class.

DATA

Although the total station procedure has many potential advantages, the one which was analysed in depth was the reduction in 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 using accident investigation work logs. Additionally, accident clearance times were documented for a much larger sample of accidents in order to determine the extent to which total station procedures would likely prove advantageous.

Field Investigation Information

An accident investigation work log, shown in Figure 1, was completed by both the Kentucky State Police (KSP) and the Lexington-Fayette Urban County Government police (LFUCGP) after they investigated an accident using the total station equipment. The log was used to document the number of times the equipment was used and the value of its use.

For each accident, general information relating to the road type, type of accident, number and type of vehicles involved, and accident severity were entered into the work log. Also entered into the log was information concerning data collection including the time to collect the data, the number of measurements, the number of officers and man-hours required to collect the data, the road closure time, and the time to prepare the accident diagram.

The KSP investigated seven accidents using both the total station equipment and the coordinate procedure. In those instances, information was obtained for both methodologies. Also, a review was performed of records of past accident investigations by the LFUCGP where the coordinate procedure was used.

Accident Scene Clearance Times

The time required for the field investigation was among the items reported on the accident investigation work log. Because the sample of accidents for which work logs were prepared was small, independent estimates of the time to clear the accident scene were desired. Fortunately, the uniform accident report identifies both the time police arrive at an accident scene as well as the time the scene is cleared, that is, the time traffic returns to its normal movement. It should be noted that the "scene cleared" time would not necessarily be the time that the on-scene investigation was concluded if the investigation continued after traffic returned to normal movement. However, the investigation is typically concluded before traffic returns to normal flow. These two times, the data collection time and the accident clearance time, helped gauge the potential effects of any improvements associated with the use of total station equipment. These two times also provided a means to estimate the time required to investigate an accident.

Using a computerized file of traffic accidents for the period of 1991 through 1993, summaries were obtained for both Fayette County and statewide. Average clearance times were obtained as a function of several variables such as accident severity, highway type, vehicle type, number of vehicles, and type of accident. The number of accidents requiring excessive clearance times is an indication of the potential value of total station equipment.

RESULTS

Field Investigation

Information recorded on the investigation work log (Figure 1) was summarized. A comparison of results using either the total station or the coordinate procedures was made. As shown in Table 2, the average number of measurements taken at a given location, the average data collection time to complete the investigation, the average number of man-hours required to complete the investigation, and the number of measurements per man-hour were compared.

In a one-year period, the total station procedure was used a total of 32 times by the KSP and 16 times by the LFUCG police. The results of using this procedure, compared to the coordinate procedure, are shown in Table 2. The average number of measurements per site was approximately doubled when the survey equipment was used, while the time and man-hours required to collect the data decreased substantially. The time to collect the data decreased from slightly over three hours to about two hours. The number of measurements per man-hour increased dramatically using the total station equipment.

Using prior LFUCG police accident reports, substantial data were available in which the coordinate procedure was used. A summary of these data is also given in Table 2. The times given for the coordinate method taken by the LFUCG police were the clearance times obtained from the police reports. The data analysis for the measurements was based on the number of measurements given on the police report. A comparison showed that, using the LFUCG police data, the measurements per man-hour increased by a factor of slightly over three using the total station procedure, as compared to the coordinate procedure.

At seven locations where the KSP investigated an accident, both the coordinate and total station procedures were used. In these situations, the scene was originally measured using the coordinate procedure with the total station procedure used later. At these sites, three times as many measurements were taken using the total station procedure in approximately one-half the time.

A similar type of analysis was also conducted considering other information given on the work log. Accident severity, road type, number of vehicles, and type of vehicle are factors which may affect the time required to collect data at an accident site. The results of this analysis are given in Tables 3 and 4. The data from the LFUCG police were used for the coordinate method since a large sample of data was available. Data from both the KSP and LFUCG police were used for the total station procedure.

The time required by the LFUCG police to collect data using the coordinate procedure at 124 accident sites is summarized in Table 3. It is shown that the time to collect data was largest: on interstates, for accidents involving more than three vehicles, and for accidents involving trucks. Also, the time to investigate fatal accidents was substantially larger than that for injury accidents.

The same general trends for road type, number of vehicles, and vehicle type were found when the surveying equipment was used (Table 4), but the man-hours required to collect the data were dramatically reduced. The data show that this 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 for injury or fatal accidents.

Discussions were held with the officers using total station equipment to obtain their opinions and observations. All comments were positive concerning the total station equipment. The concensus was that this equipment allowed more accurate and more detailed measurments to be collected in a less time. While a short period of time was required to become familiar with the operation of the equipment, it was not found to be difficult to operate. The equipment could not easily be used during certain weather conditions such as rain or heavy fog. In some instances, points to be measured were initially marked with paint with the surveying equipment used at a later time.

Accident Diagram

Measurements taken at the accident scene can be used to prepare a scaled accident diagram. While only a rough diagram of the accident scene is prepared in many cases, it may be necessary or desirable to prepare a scaled accident diagram to present the data. 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 using data from either the coordinate or the surveying procedures.

The information revealed that the time savings associated with preparing the accident diagram using the total station procedure, compared to the coordinate procedure, was at least of the magnitude associated with the data collection. Discussions with the police officers indicated that the time to prepare detailed diagrams was decreased by at least 50 percent using the total station procedure. Only a few officers were involved in the preparation of diagrams.

The total station procedure provided a more automated method with substantially more data points. This resulted in a more accurate diagram being prepared in less time. A example of an accident diagram prepared using this procedure is given in Figure 2.

Benefit Cost Analysis

A comparison was made between the cost of purchasing the equipment necessary to utilize the total station procedure and the primary benefits thought to be associated with this procedure. A method to quantify the benefits was developed. The primary benefit to the police agency is the reduction in man-hours required to investigate a traffic accident and to prepare an accident diagram. The major cost benefits, however, would be to motorists in terms of reduced delay (time cost) and fuel consumption (fuel cost). In order to compare benefits and costs, delay and fuel savings were estimated and compared to equipment costs.

A review of literature was conducted to determine appropriate values to use for the costs of time and fuel. Time cost was estimated using a cost per vehicle hour of delay. Costs per vehicle hour of delay were determined to be in the range of $6.25 to $7.00 (2,3,4). The fuel cost was estimated by assuming that each vehicle hour of delay uses about 1.1 gallons of fuel (4) along with a fuel cost of $ 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 to use the total station procedure was determined to be about $15,000 per unit. An additional cost of about $10,000 would be associated with the equipment used in the preparation of accident diagrams. The plotting equipment would typically be used for more than one set of field equipment. The costs for time and fuel result in a total savings of approximately $8.00 per vehicle hour of delay saved. Given a maximum cost of

$25,000 to implement a total station procedure, a reduction of 3,125 vehicle hours in delay would be necessary to pay for the equipment. Training cost would be included in the implementation cost.

The potential vehicle hours saved must be estimated to compute the associated delay and fuel savings. The savings in delay were estimated using the reduction in time required to investigate an accident using the total station equipment. This savings in time required to investigate an accident was estimated using the accident investigation work log data.

The data indicate that the time required to investigate an accident was reduced by about 60 minutes when using the total station procedure compared to the coordinate procedure. The typical traffic investigation took about 180 minutes using the coordinate method compared to about 120 minutes using the total station procedure. The total station equipment was typically only used in severe accidents where a long investigation time would be required. The average travel time for drivers traveling through the accident site during the accident investigation would be reduced using the total station procedure.

Various scenarios were used to estimate the reduction in vehicle delay and fuel costs associated with time savings from use of the total station procedure. In some accident investigations, the road would be blocked for a portion of the time while in other cases traffic flow would continue but at a slower speed. In all cases, the travel time would be increased during the time of the investigation and data collection. 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 shown in Figure 3. The stopped delay (in vehicle hours) is represented by the shaded areas in this figure.

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

Estimates were made for a four-lane freeway (one direction) and for a two-lane roadway. For all three scenarios, it was assumed that the departure rate following completion of the accident investigation was 3,600 vehicles per hour (vph) in one direction for the freeway and 1,800 vph 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 using the coordinate and total station procedures. Since the total station procedure is less disruptive to traffic, an additional savings in delay would be gained from this factor.

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 three minutes were alternately allocated to each direction followed by a 30-second dead interval. This yielded a seven-minute cycle time for use of the open lane.

Accidents occur on all types of roads under a variety of traffic volume levels. The average annual daily traffic (ADT) on state maintained, rural, two-lane roads in Kentucky is about 1,500 compared to about 6,900 in urban areas (5). The average ADT on four-lane divided (non-interstate or parkway) roadways vary from 8,800 in rural areas to 21,500 in urban areas. Average ADTs on rural interstates are 21,400 compared to 53,700 on urban interstates. The average ADT on all rural roads is about 2,200 compared to 14,500 on urban roadways. The range in traffic volumes to use in the analysis was estimated using this statewide average volume data as a guide.

The vehicle hours of delay associated with an accident investigation was estimated 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 steady-state. The results of the analysis are summarized in Figures 4 and 5.

The freeway analysis is presented in Figure 4. The approach one-way flow rate was analysed up to a traffic volume of 2,000 vph. The reduction in vehicle hours of delay associated with reducing the investigation time from three to two hours was estimated using the assumptions of complete blockage where there would be no flow as well as for partial blockage with obstructed one-way flow rates of 500, 1,000 and 1,500 vph. For example, if an approach flow rate of 1,000 vph is reduced to 500 vph during the investigation, 1,500 vehicle hours of delay can be eliminated by reducing the investigation time from three to two hours.

The two-lane, two-way road obstruction analysis is presented in Figure 5. The approach two-way flow rate was analysed up to a level of 1,000 vph. In addition to complete blockage, which would result in no flow, obstructed one-way flow rates of 250, 500, and 750 vph were assumed. For example, if an approach two-way flow rate of 500 vph is reduced to an intermittant, obstructed one-way flow rate of 250 vph during the investigation, a reduction of about 800 vehicle hours of delay can be obtained.

Using the time and fuel cost 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 to the cost of $25,000 for the total station equipment and training, it can be shown that the estimated benefits will pay for the cost of the equipment after the investigation of a relatively small number of accidents. The break-even point requires a savings of 3,125 hours of delay.

During high volume periods, the savings associated with using the total station equipment would pay for the equipment after only a couple of accidents. Even for low volume conditions, the delay savings would pay for the equipment after as few as about 10 accident investigations. Given the potential use of the equipment, this savings in motorists delay will pay for the cost of the equipment in no more than a few months and possibly within a few weeks (depending on the types of accident and location where the equipment is used).

The above 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, traveller benefits can be quite substantial even with time savings considerably smaller than the one hour that has been assumed, particularly when traffic volumes are large. For example, traveller benefits exceed total station purchase costs after only three accident investigations which reduce 60-minute blockages by five minutes on four-lane freeways carrying approximately 3,000 vehicles per hour in the blocked direction.

Accident Clearance Times

The time necessary to clear an accident scene can be determined using information given on the police report. The time between when the police arrived and when the scene was cleared for traffic to return to its normal movement is defined as the clearance time. These times are given on the police report and coded on the statewide computer tape. An analyis was performed to determine the average and distribution of clearance times in Fayette County as well as statewide. Average clearance times were also compared to several variables. Data were analysed for the period of 1991 through 1993.

The number of accidents with large clearance times provides an indication of the potential frequency of highly productive applications of the survey equipment. However, the determining factor in clearance times can be other than the accident investigation. Cleaning up spills or removing vehicles are examples of other reasons for large clearance times. In those instances, reducing the investigation time will not reduce the clearance time.

The average clearance time for an accident in Fayette County was 70 minutes. This compares to an average of 51 minutes statewide. The distribution of clearance times is given in Table 5. In Fayette County, almost one-half of the clearance times was 15 minutes or less and approximately two-thirds were 30 minutes or less. Statewide statistics also show that about two-thirds of the clearance times were 30 minutes or less.

About seven percent of all accidents in Fayette County had a clearance time of over five hours compared to 3.5 percent statewide. These are the types of accidents in which use of the total station equipment can be beneficial. In one year, this represents about 840 accidents in Fayette County and about 4,800 statewide. This shows there is a substantial number of accidents in which total station equipment could be used in a highly effective manner. Of course, in many of these accidents, factors other than the accident investigation contributed to the high clearance time.

An analysis by county is given in Table 6. For each county, the average clearance time is given along with the percentages of clearance times over one, two, and five hours. There was a large range in average clearance times with 11 counties having an average time of over 120 minutes and three with an average of over 180 minutes while five counties had an average time of under 30 minutes. Those counties with average clearance times over 180 minutes were Carlisle (205 minutes), Edmonson (200 minutes), and Robertson (233 minutes). Those counties with average clearance times under 30 minutes were Campbell (28 minutes), Daviess (29 minutes), Hardin (25 minutes), Jefferson (26 minutes), and Wayne (29 minutes).

Approximately one-third of all counties had an average clearance time of 45 minutes or less. About two-thirds had an average clearance time of 60 minutes or less. Only 15 counties had an average clearance time of over 90 minutes.

As shown in Table 7, clearance times are related to several accident variables. The clearance time for fatal accidents is much longer than for injury or property-damage-only accidents. Accidents between midnight and 6 a.m. have long clearance times which is in agreement with the finding that clearance times for nighttime accidents are longer than for daytime accidents. Accidents involving trucks have a longer clearance time than when no truck is involved. Clearance times for single vehicle accidents are longer than for multiple vehicle accidents. This is related to the severity of the accidents and is consistent with the finding that fixed-object and non-collison (single vehicle) accidents have longer clearance times than other-vehicle collisions. The clearance time for accidents involving four or more vehicles increased over those involving two or three vehicles. This would be related to the time to remove the vehicles. Accidents on interstates and parkways have longer clearance times than other highway types. Clearance times are longer for non-intersection than for intersection accidents as well as in rural areas compared to other land use categories.

CONCLUSIONS

The analysis shows that the investigation of traffic accidents using total station (survey) equipment provides a substantial improvement over the traditional coordinate procedure. The number of measurements obtained at an accident scene increased (by a factor of about two) when the total station equipment was used while the time required to collect the measurements decreased by about 33 percent with the 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 than typically obtained with the coordinate procedure. The use of computer plotting in the total station procedure results in a significant time savings when a detailed accident diagram is needed.

More importantly, 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 a savings which would pay for its cost after only a very few investigations. This indicates that the use of this type of equipment for accident investigation is economically justified. The greatest benefit would be at high volume locations where a substantial amount of data is necessary.

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

RECOMMENDATIONS

It is recommended that the use of total station equipment be continued. Additional equipment should be purchased as funds become available. Specifically, each KSP post should have this equipment as well as other police departments having 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 accident cases to ensure that optimum use is made of the equipment. As use of this equipment increases a uniform data collection coding system would be beneficial.

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TABLE 1. TOTAL STATION EQUIPMENT AND COST

EQUIPMENT	NUMBER KSP	NUMBER LFUCG	COST* KSP	COST* LFUCG
Leitz Total Station and Supplies	3	2	$31,052	$20,702
Notebook Computers 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	5	1	899	199
Laser Printer		1	700	725
Computer Equipment	1	1	1,525	1,525
Printing Supplies			554	734
Total			$63,934	$38,194

* Purchase price in 1993.

TABLE 2. COMPARISON OF COORDINATE AND TOTAL STATION DATA COLLECTION METHODS

	KSP	LFUCG
Coordinate Method		
Number Accidents	7 *	124 **
Average Number of Measurements	36	48
Average Data Collection Time (Hours)	3.6	3.1
Average Number of Man-Hours	11.9	10.8
Measurements per Man-Hour	3.0	4.5
Total Station Method		
Number Accidents	32	16
Average Number of Measurements	84	97
Average Data Collection Time (Hours)	1.9	2.1
Average Number of Man-Hours	4.5	6.7
Measurements per Man-Hour	18.5	14.4

* 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.

** These data are based on clearance times given on the police report and the number of measurements given in the report.

TABLE 3. VARIABLES AFFECTING DATA COLLECTION TIME (COORDINATE PROCEDURE - LFUCG POLICE)

VARIABLE	NUMBER ACCIDENTS	AVERAGE NO. MEASUREMENTS	AVERAGE TIME (HOURS)	AVERAGE MAN-HOURS
Road Type*				
Two-Lane	69	48	3.2	10.4
Four-Lane	42	45	3.0	9.9
Interstate	8	72	4.5	21.0
Number Vehicles				
One	66	40	2.9	8.9
Two	46	55	3.3	12.0
Three	7	68	3.7	13.8
Over Three	5	65	4.1	20.7
Vehicle Type				
Cars Only	117	46	3.0	9.9
Truck Involved	7	78	4.9	24.8
Severity**				
Fatality	62	54	3.4	12.8
Injury	60	41	2.8	8.6
All	124	48	3.1	10.8

* Does not include a few accidents in parking lots and where the road type was unknown.

** Does not include two property-damage-only accidents.

TABLE 4. VARIABLES AFFECTING DATA COLLECTION TIME (TOTAL STATION PROCEDURE - KSP AND LFUCG POLICE)

VARIABLE	NUMBER ACCIDENTS	AVERAGE NO. MEASUREMENTS	AVERAGE TIME (HOURS)	AVERAGE MAN-HOURS
Road Type*				
Two-Lane	30	85	1.8	4.5
Four-Lane	11	113	2.2	7.1
Interstate	6	65	2.4	6.8
Number Vehicles				
One	7	87	1.6	5.0
Two	29	87	2.0	5.2
Three	8	85	1.8	4.3
Over Three	3	125	2.7	9.1
Vehicle Type				
Cars Only	38	88	1.8	5.1
Truck Involved	8	85	2.3	5.8
Severity				
Fatality	32	94	2.1	5.5
Injury	8	100	1.9	6.4
Property Damage	7	57	1.3	3.2
All	48	88	2.0	5.2

* Accidents do not total 48 when information for given variable was unknown.

TABLE 5. DISTRIBUTION OF CLEARANCE TIMES (1991-1993)

TIME RANGE (MINUTES)	PERCENT IN TIME RANGE FAYETTE 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

TABLE 6. CLEARANCE TIMES BY COUNTY (1991 - 1993)

COUNTY	NUMBER OF ACCIDENTS	AVERAGE CLEARANCE TIME (MINUTES)	CLEARANCE TIME OVER 1 HOUR (PERCENT)	CLEARANCE TIME OVER 2 HOURS (PERCENT)	CLEARANCE TIME OVER 5 HOURS (PERCENT)
Adair	1,577	61	10.4	6.1	4.9
Allen	1,451	49	10.6	5.3	3.8
Anderson	1,304	42	9.9	2.8	1.8
Ballard	616	90	21.3	9.7	6.3
Barren	3,822	54	8.1	5.3	4.1
Bath	993	78	16.3	8.4	5.4
Bell	2,631	36	8.0	2.2	0.7
Boone	9,833	163	25.8	22.6	19.3
Bourbon	2,313	90	18.0	10.0	7.9
Boyd	6,500	44	9.7	3.9	2.5
Boyle	3,224	32	6.0	1.5	0.9
Bracken	611	53	14.1	5.1	2.3
Breathitt	1,271	39	12.8	3.7	0.7
Breckinridge	1,005	40	11.8	1.1	0.7
Bullitt	3,894	38	10.2	2.3	0.7
Butler	893	69	15.2	9.3	6.9
Caldwell	1,277	38	8.5	3.0	1.6
Calloway	1,025	45	10.1	3.5	1.9
Campbell	9,054	28	4.4	1.3	0.8
Carlisle	170	205	38.8	28.8	22.4
Carroll	1,305	122	22.5	15.9	13.0
Carter	1,991	66	13.0	6.1	4.5
Casey	594	129	23.9	16.8	13.3
Christian	6,389	60	12.1	6.7	5.0
Clark	3,331	32	6.8	1.8	0.8
Clay	1,331	65	13.1	7.5	5.5
Clinton	813	39	6.2	2.8	2.1
Crittenden	665	40	7.7	3.3	2.1
Cumberland	448	51	8.7	4.0	3.1
Daviess	11,655	29	5.2	1.2	0.6
Edmonson	779	200	35.3	26.6	23.2
Elliott	263	66	33.5	8.4	1.1
Estill	1,039	39	8.2	2.1	1.3
Fayette	36,449	70	13.0	8.6	7.0
Fleming	967	44	11.0	2.5	1.2
Floyd	3,912	54	14.2	5.0	2.6
Franklin	5,447	57	10.3	5.2	4.2
Fulton	821	33	5.7	1.9	1.1
Gallatin	588	97	20.7	8.8	7.0
Garrard	775	103	17.7	13.2	10.1
Grant	2,214	139	25.4	16.1	14.4
Graves	3,233	45	11.4	3.9	2.0
Grayson	2,083	32	8.7	1.6	0.5
Green	766	51	11.1	4.7	3.4

TABLE 6. CLEARANCE TIMES BY COUNTY (1991 - 1993) (continued)

COUNTY	NUMBER OF ACCIDENTS	AVERAGE CLEARANCE TIME (MINUTES)	CLEARANCE TIME OVER 1 HOUR (PERCENT)	CLEARANCE TIME OVER 2 HOURS (PERCENT)	CLEARANCE TIME OVER 5 HOURS (PERCENT)
Greenup	2,675	61	14.5	5.3	4.0
Hancock	499	60	15.8	5.4	2.8
Hardin	8,673	25	4.7	1.2	0.3
Harlan	2,735	46	10.6	3.9	1.9
Harrison	1,723	54	11.1	5.3	3.8
Hart	1,364	97	23.9	11.3	8.3
Henderson	6,594	58	10.8	5.7	4.5
Henry	1,285	136	27.2	16.0	12.8
Hickman	263	72	22.4	11.8	3.8
Hopkins	5,998	64	11.6	7.2	5.3
Jackson	608	46	10.4	3.6	1.6
Jefferson	88,287	26	4.8	1.1	0.4
Jessamine	3,432	35	8.4	2.0	0.7
Johnson	1,843	35	8.8	2.1	1.0
Kenton	17,977	51	8.1	4.9	3.9
Knott	1,010	48	16.0	4.5	1.2
Knox	2,098	68	12.0	6.8	4.8
Larue	1,019	43	9.6	3.6	2.3
Laurel	4,162	75	13.4	7.7	6.5
Lawrence	869	42	10.7	3.2	1.4
Lee	417	48	8.6	4.6	4.1
Leslie	486	43	13.8	4.1	0.8
Letcher	1,842	44	13.8	3.9	1.1
Lewis	884	81	20.7	10.4	6.2
Lincoln	1,523	78	16.1	8.3	6.2
Livingston	583	66	15.4	6.9	3.8
Logan	2,203	34	9.5	2.1	0.8
Lyon	550	65	24.0	8.0	3.1
McCracken	10,179	44	8.9	3.5	2.4
McCreary	760	87	23.0	10.0	7.0
McLean	632	63	19.0	7.6	3.6
Madison	7,881	38	8.1	2.4	1.3
Magoffin	818	52	13.8	3.3	1.5
Marion	1,565	77	15.1	8.3	5.6
Marshall	2,196	49	12.3	3.5	1.9
Martin	1,042	72	13.3	8.0	4.9
Mason	2,970	40	6.4	3.0	2.4
Meade	1,530	37	12.2	1.8	0.7
Menifee	274	175	37.2	25.9	18.2
Mercer	2,108	109	19.2	14.5	11.9
Metcalfe	565	53	10.8	5.3	3.2
Monroe	594	37	5.4	2.2	1.9
Montgomery	2,163	38	7.6	3.2	1.8
Morgan	872	82	27.4	9.7	5.6

TABLE 6. CLEARANCE TIMES BY COUNTY (1991 - 1993) (continued)

COUNTY	NUMBER OF ACCIDENTS	AVERAGE CLEARANCE TIME (MINUTES)	CLEARANCE TIME OVER 1 HOUR (PERCENT)	CLEARANCE TIME OVER 2 HOURS (PERCENT)	CLEARANCE TIME OVER 5 HOURS (PERCENT)
Muhlenberg	3,121	76	13.1	7.7	6.1
Nelson	3,079	33	8.9	1.5	0.5
Nicholas	413	44	8.2	4.4	2.7
Ohio	1,809	56	15.9	5.6	3.0
Oldham	2,619	54	14.6	5.6	3.4
Owen	741	58	17.8	5.8	2.0
Owsley	286	49	9.4	3.8	2.1
Pendleton	905	58	15.7	5.1	3.5
Perry	3,390	32	9.3	2.6	0.7
Pike	7,560	56	14.1	5.3	3.1
Powell	862	76	15.4	7.7	5.9
Pulaski	5,184	43	7.7	3.9	2.9
Robertson	42	233	31.0	23.8	21.4
Rockcastle	1,366	61	16.5	5.3	3.2
Rowan	2,709	55	13.5	5.8	4.0
Russell	1,272	52	22.5	5.0	3.1
Scott	3,619	40	11.5	2.6	0.9
Shelby	3,277	46	16.3	3.3	1.1
Simpson	1,639	48	8.4	4.1	2.7
Spencer	439	44	17.3	2.5	0.7
Taylor	2,367	53	8.8	5.4	4.7
Todd	831	57	14.1	4.8	2.8
Trigg	1,044	53	21.3	9.8	6.4
Trimble	479	76	20.7	7.9	4.4
Union	1,419	76	14.2	8.1	5.8
Warren	13,094	56	8.5	5.8	5.0
Washington	868	66	16.9	6.8	4.8
Wayne	1,408	29	3.9	1.2	0.9
Webster	1,154	56	15.3	5.5	2.7
Whitley	2,829	157	25.5	20.9	17.6
Wolfe	623	135	28.1	17.8	13.3
Woodford	2,308	34	7.3	1.9	0.7

TABLE 7. CLEARANCE TIME VERSUS SEVERAL VARIABLES

		AVERAGE CLEARANCE TIME (MINUTES)	
VARIABLE	CATEGORY	FAYETTE 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
Lane Use	Rural	79	75
	Business	55	37
	Residential	60	43
	Limited Access	76	68

Figure 1. Work Log.

ACCIDENT INVESTIGATION WORK LOG
TOTAL STATION PROCEDURE

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 _____
MANHOURS TO TAKE MEASUREMENTS _____
TOTAL ROAD CLOSURE TIME ______
COMMENTS ____
____
____

ACCIDENT DIAGRAM:

TIME TO PREPARE DIAGRAM _____
MANHOURS TO PREPARE DIAGRAM _____
COMMENTS ____
____
____

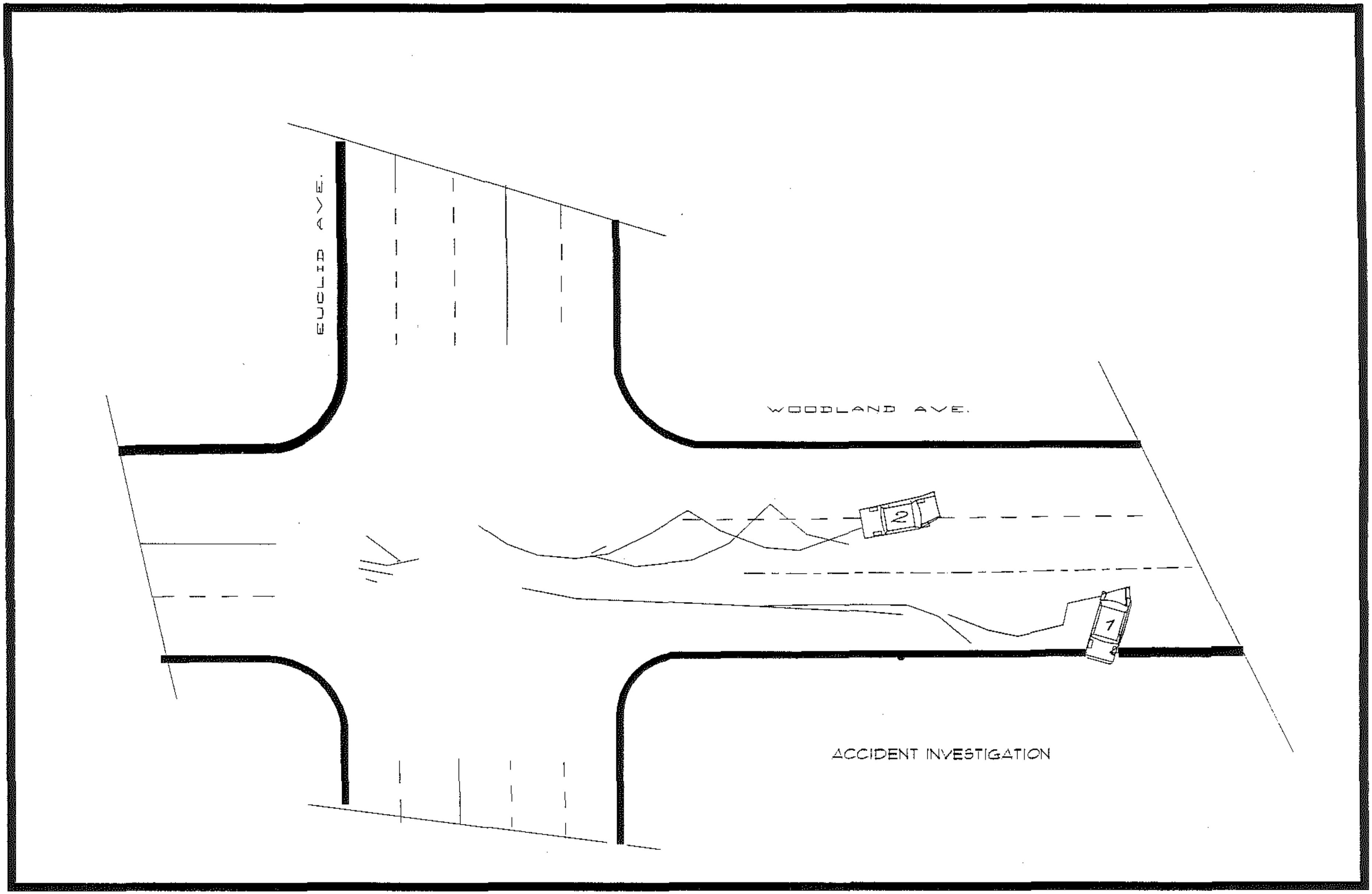

Figure 2. Accident Diagram Using Total Station Procedure.

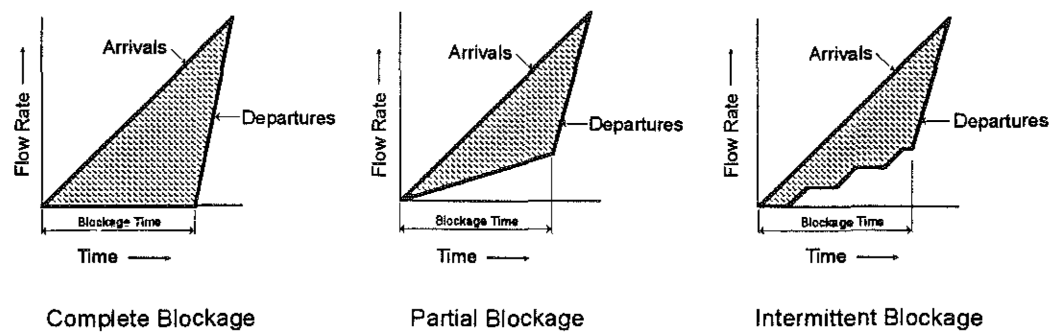

Figure 3. Graphical Description of Assumed Departures for Complete, Partial, or Intermittent Blockages.

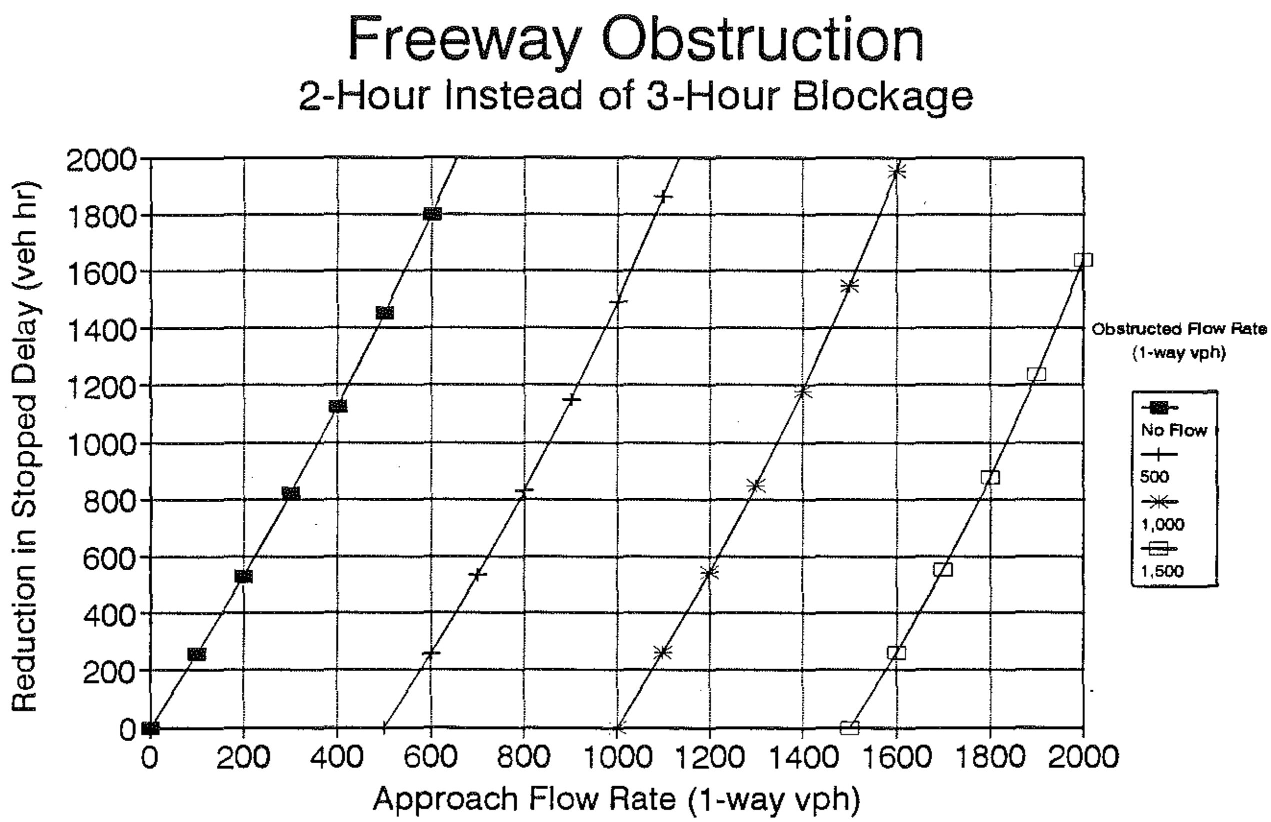

Figure 4. Reduction in Stopped Delay on a Freeway Associated with Use of Total Station Equipment.

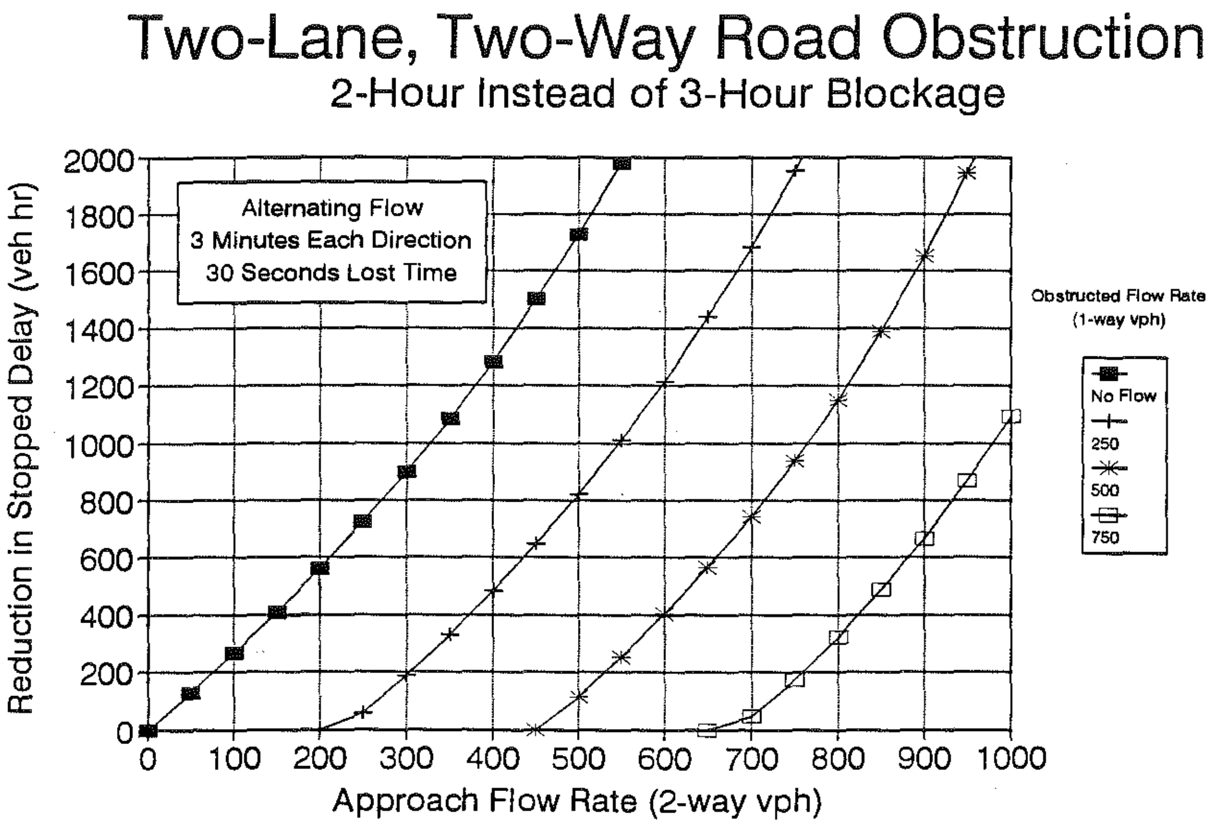

Figure 5. Reduction in Stopped Delay on a Two Lane Highway Associated with Use of Total Station Equipment.