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DEVELOPMENT OF DATA MEASURMENT TECHNIQUES FOR TRAFFIC OPERATIONS ANALYSIS AT INTERSECTIONS

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16. Abstract

This study was undertaken for the purpose of developing intersection data collection methods and approaches which reflect the current needs of engineers and the state-of-the-art capabilities of available equipment. A literature review summarizes previous work which is pertinent to intersection studies and data collection. Interviews were conducted with personnel from city, county and state agencies to determine study equipment availability, desired equipment, personnel resources, types of studies that are conducted, and general problems that are related to intersection data collection. A set of study method selection factors were developed. An evaluation focused on investigating the application of photographic and television equipment with studies to determine the time required for data reduction when using these approaches to data collection. For the conditions in Arizona, the use of photographic and video equipment represents a feasible alternative to data collection methods which are more labor intensive.

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INTRODUCTION

Field data collection continues to represent a major cost in the conduct of any traffic study. Significant portions of study budgets must be allocated to the acquisition, collection, and reduction of the field data. In many cases, the time and resources that are necessary for the data collection phases are out of proportion to the efforts that are devoted to the actual analysis and determination of the preferred solution to a problem.

In considering traffic studies which involve the collection of field data, it is important to recognize the purpose and function for which the data will be applied. Certainly, the acquisition of data which are not needed can result in expenditures that are unnecessary for the solution of a problem. The guidelines for field studies which have been developed to date only provide some limited degree of input in terms of the comparison of the various approaches, methods, and equipment. Frequently, the engineer may not know the incremental cost of the collection of additional pertinent measures of traffic performance.

A major constraint which must be recognized in data collection is the amount of data that an individual can record in a time period if manual methods are utilized. Where significant amounts of data are to be recorded in a limited period of time, the size of the study team must be increased so that the recording requirements on an individual do not exceed the capabilities of that person.

For intersections, it is necessary to manually collect much of the information for the analysis of traffic operations at a specific location. Turn movement and delay studies are examples of situations where manual data collection methods have generally been necessary. When the manual techniques are utilized, the resulting data are subject to human error; and it is difficult or even impossible to validate the data if an error is suspected. If there is a question of an error, it may be necessary to completely repeat the entire field data collection effort.

Because of their duties, there is a limit to the amount of time that highway and traffic engineers may spend in the field observing traffic at a given site. While it may be desirable, it is not always possible for an engineer to personally visit a site to acquire first hand information about a condition. In order to assess a situation, the engineers must rely on data for guidance in evaluating problems and assessing alternative courses of action which may be considered.

When utilizing reliable data from a particular study, there is a question as to whether the available information will actually reveal the nature or cause of a problem. Even in situations where field studies are undertaken in response to an apparent problem, it is possible that the results of the field studies may not provide the needed information which truly identifies the cause of the problem. In some cases, conventional traffic study methodologies may not provide such data or information. During the course of the field studies, it is necessary to rely on the field study team to observe and note other information which may be pertinent.

At the same time that engineers are faced with the problem of collecting reliable and pertinent data within the available resources, there have been advances in analysis procedures and methodologies which require increasing amounts of data. This places new dimensions on the scope of the field data collection problem. For example, the new Highway Capacity Manual will utilize stop time delay as the measure of level of service for signalized intersections. Some of the new computer based analyses require extensive data bases. Such changes in analysis procedures and methodologies require highway and traffic engineers to reconsider the types and amount of data that should be collected as well as the method that are used to economically acquire the needed data.

The advances in electronic and microcomputer technology potenially affect possible approaches to traffic data collection. These advances not only apply to the actual data collection process, but may also have an impact on the analysis process as well. In view of the fact that intersection analyses may require more information about traffic for a comprehensive assessment, these concepts and approaches to field studies may become viable for wide scale use. In some cases, this equipment may have the capability to provide a portrayal of the operation of an intersection in a central office where numerous engineers can provide input on the various aspects of potential traffic problems.

STUDY OBJECTIVES

Given the intersection data collection problem, the general objective of this study is to develop intersection data collection methods and approaches which reflect current needs of engineers and the state-of-the-art capabilities of available equipment. The methods and approaches should be capable of presenting data such as traffic flow measures, traffic conflicts, turn movements, vehicle delay, and driver behavior. More specifically, the study focused on accomplishing the following:

(a) Determine the data collection requirements and the techniques currently utilized by state, county, and city traffic engineers in Arizona.

(b) Determine study methods and approaches which may be utilized to meet the data requirement needs.

(c) Conduct a comprehensive evaluation of the various study methods and approaches in terms of data needs.

(d) Develop recommended procedures and approaches for intersection studies.

(e) Develop a demonstration of recommended procedures and approaches.

LIMITATIONS IN SCOPE OF STUDY

While the study was to examine the variety of equipment that could be utilized in the conduct of intersection field studies, the work did not include the development of new equipment. It was anticipated, however, that the results of the work could give direction to concepts for new data collection equipment.

LITERATURE REVIEW

Field data collection has been recognized as an integral part of traffic studies, traffic engineering programs, and the solution of traffic problems for many years. A review of the traffic engineering literature reveals considerable discussion of traffic surveys and studies. The overall role and function of traffic studies are certainly not new to traffic engineering activities as is evident from the discussion contained in the first edition of the Traffic Engineering Handbook(1). In this early publication, the basic objectives, planning, and conduct of traffic studies are presented. Even at that time, specific procedures were outlined with respect to the conduct and required equipment for commonly used traffic studies.

Over the years, a number of publications have been developed or evolved which provide guidance to engineers in terms of traffic studies and procedures. The first edition of the Manual of Traffic Engineering Studies was published in 1945 by the Association of Casualty & Surety Companies. The more recent edition(2) was published in 1976 by the Institute of Transportation Engineers and is a commonly referenced source for information related to traffic studies.

In 1958, the National Committee on Urban Transportation of the Public Administration Service published a series of manuals(3) which focused on procedures for metropolitan area types of traffic studies. These manuals served to supplement a handbook(4) which was designed to aid metropolitan transportation planning through the systematic collection and analysis of basic facts.

More recently, the Federal Highway Administration has published several documents[5,6,7,8] which contain extensive discussions of field data collection. These publications are more oriented to data collection and analyses in connection with traffic operations and safety problems.

Two of these documents[5,6] were prepared as part of a series of publications on positive guidance. One of the volumes[5] specifically addresses the role of evaluation with respect to traffic operations, safety, and positive guidance projects. In addition, the steps that are included in the development of an evaluation plan are presented. Inherent in the evaluation plan is the identification of the measures of effectiveness which will be used to diagnose the problem and evaluate the improvement as well as define the selection of the data collection methods. The identification of measures of effectiveness basically defines the data types and requirements.

The other document in this series[6] focuses on the planning and field data collection phases of a project. In addition, the second part of this publication provides guidelines for collecting data for specific measures of performance. Tables 1, 2, and 3 are taken from this publication. Table 1 indicates the measures of effectiveness for typical highway situations, and Table 2 shows the measures of effectiveness for typical traffic control devices. Table 3 identifies the applicable data collection techniques given the various measures of effectiveness. In Table 3, it can be noted that data collection

TABLE 1

MEASURES OF EFFECTIVENESS FOR TYPICAL HIGHWAY SITUATIONS(6)

SITUATION	MOE's	SITUATION	MOE's
ALIGNMENT, HORIZONTAL CURVE	Spot Speed: Upstream; Entry; Apex; Exit; Downstream. Lateral Placement. Encroachments; Shoulder; Centerline. Brake Applications.	MERGE	Merge speed profile. Conflicts with through stream. Distribution of merges. Delay. Brake Applications
ALIGNMENT, VERTICAL CURVE	Spot Speed: Upstream Entry; Sag (or); Crest; Downstream. Brake Applications. Time Headway (Downgrade).	HARBOR BRIDGES	Speed. Lateral Placement. Centerline Encroachment.
		OBSTACLES	Speed. Lateral Placement.
CONSTRUCTION AND MAINTENANCE ZONES	Brake Applications. Conflicts. Delay; Encroachments. Lateral Placement. Last-Minute Lane Changes. Speed.	PASSING ZONES	Passing Frequency. Passing and Return Type. Number of Abortive Passes. Conflicts With Oncoming or Overtaken Vehicles.
CHANGE IN CROSS SECTION - Lane, Shoulder Width Reduction	Spot Speed. Brake Applications. Lateral Placement.	PEDESTRIAN CROSSING; SCHOOL CROSSING	Compliance. Conflicts. Speed. Delay.
INTERCHANGES, DIVERGE AREAS	Distribution of Points of Entry into Inside Lane; Deceleration Lane. Speed; Mainstream (Reduction): at Gore Area; on Ramp. Deceleration Lane Speed Profile. Erratic movements.	RAILROAD CROSSING	Head Turning Movements. Speed. Speed Profile.
		STOP APPROACH	Speed Profile. Lateral Placement. Brake Applications. Encroachments on Cross Roadway. Erratic Deceleration.
INTERCHANGES LEFT EXITS TANGENTIAL OFF RAMPS	Erratic Movements Conflicts. Speed. Lateral Placement.	TURN	Location of Lane Changes Enter Deceleration Lane. Spot Speeds: Upstream; Entry. Point of Entry into Deceleration Lane. Erratic Maneuvers. Conflicts: Opposing, Through Vehicles. Time Through Intersection
INTERSECTIONS, SIGNALIZED	Conflicts. Delay. Travel Time. Time Through Intersection. Speed. Lateral Placement. Brake Applications. Stop Line Encroachment.	TOLL PLAZAS	Speed. Lateral Placement. Conflicts.
LANE DROPS	Spot Speed: Upstream; Vicinity of Sign; Beginning Taper; End Taper. Distribution of Lane Changes. Merging Conflicts. Encroachments. Lateral Placement Through Transition Area.	WEAVING SECTIONS	Speed Speed Charge. Brake Light Applications.

TABLE 2

MEASURES OF EFFECTIVENESS FOR TYPICAL TRAFFIC CONTROL DEVICES (6)

DEVICE	MOE
MARKINGS	* Lateral Placement * Encroachments * Compliance
GUIDE SIGNS	* High Risk Gore Weaves (Erratic Maneuvers) * Gore Weaves (Erratic Maneuvers) * Driving Slowly * Late Lane Changes * Brake Light Applications * Energy Efficiency
WARNING SIGNS	* Speed (Profile) (Spot) * Lateral Placement * Brake Light Indications * Stop Line Conflicts * Compliance
SIGNALS	* Conflicts * Speed * Compliance * Energy Efficiency

TABLE 3

APPLICABILITY OF DATA COLLECTION TECHNIQUES(6)

MOE	DATA COLLECTION TECHNIQUE	METHOD
ACCIDENTS	Accident Records	Actuarial
BRAKE APPLICATIONS	Manual Recording	Observational
	Time-Lapse Film	Observational
	Traffic Analyzer	Observational
	Traffic Counter	Observational
	Video Recorder	Observational
	Wear Patterns	Observational
	Interview	Interactive
	Questionnaire	Interactive
COMPLIANCE	Police Records	Actuarial
	Manual Recording	Observational
	Time-Lapse Film	Observational
	Traffic Counter	Observational
	Interview	Interactive
	Questionnaire	Interactive
CONFLICTS	Manual Recording	Observational
	Time-Lapse Film	Observational
	Traffic Counter	Observational
	Video Recorder	Observational
DELAY	Compliance	Actuarial
	Aerial Photography	Observational
	Automatic Detectors	Observational
	Input-Out Studies	Observational
	Manual Recording	Observational
	Moving Vehicles	Observational
	Radar Speed Meters	Observational
	Time-Lapse Film	Observational
	Traffic Analyzer	Observational
	Traffic Counter	Observational
	Video Recorder	Observational
	Interview	Interactive
	Questionnaire	Interactive
DRIVING SLOWLY	Aerial Photography	Observational
	Input-Output Studies	Observational
	Manual Recording	Observational
	Moving Vehicles	Observational
	Radar Speed Meters	Observational
	Time-Lapse Film	Observational
	Traffic Analyzer	Observational
	Video Recorder	Observational
ENCROACHMENTS	Accident Records	Actuarial
	Traffic Counts	Actuarial
	Aerial Photography	Observational
	Automatic Detectors	Observational
	Manual Recording	Observational
	Moving Vehicles	Observational
	Time-Lapse Film	Observational
	Traffic Analyzer	Observational
	Video Recorder	Observational
	Wear Patterns	Observational
	Interviews	Interactive
	Questionnaire	Interactive
ERRATIC MOVEMENTS LAST-MINUTE LANE CHANGES	Accident Records	Actuarial
	Aerial Photography	Observational
	Automatic Detectors	Observational
	Manual Recording	Observational
	Moving Vehicles	Observational
	Time-Lapse Film	Observational
	Traffic Analyzer	Observational
	Video Recording	Observational
	Interviews	Interactive
	Questionnaire	Interactive
HEAD-TURNING MOVEMENTS	Manual Recording	Observational
	Time-Lapse Film	Observational
	Video Recording	Observational
LATERAL PLACEMENT, MERGES	Aerial Photography	Observational
	Automatic Detectors	Observational
	Manual Recording	Observational
	Moving Vehicles	Observational
	Time-Lapse Film	Observational
	Traffic Analyzer	Observational
	Video Recorder	Observational
PASSING TYPE PASSING TIME PASSING DISTANCE PASSING FREQUENCY PASSING ABORTIVE	Aerial Photography	Observational
	Manual Recording	Observational
	Moving Vehicles	Observational
	Time-Lapse Film	Observational
	Traffic Analyzer	Observational
	Video Recording	Observational
SPEED, SPEED CHANGES	Accident Records	Actuarial
	Aerial Photography	Observational
	Input-Output Studies	Observational
	Manual Recording	Observational
	Moving Vehicles	Observational
	Radar Speed Meters	Observational
	Time Lapse Film	Observational
	Traffic Analyzer	Observational
	Video Recorder	Observational
TIME HEADWAY	Aerial Photography	Observational
	Automatic Detectors	Observational
	Manual Recording	Observational
	Moving Vehicles	Observational
	Time-Lapse Film	Observational
	Traffic Analyzer	Observational
	Video Recorder	Observational
TIME THROUGH INTERSECTION TRAVEL TIME	Aerial Photography	Observational
	Automatic Detectors	Observational
	Input-Output Studies	Observational
	Manual Recording	Observational
	Moving Vehicles	Observational
	Radar Speed Meters	Observational
	Time-Lapse Film	Observational
	Traffic Analyzer	Observational
	Video Recording	Observational
VOLUME	Traffic Counts	Actuarial
	Aerial Photography	Observational
	Automatic Detectors	Observational
	Input-Output Studies	Observational
	Manual Recording	Observational
	Moving Vehicles	Observational
	Time-Lapse Film	Observational
	Traffic Analyzer	Observational
	Video Recording	Observational

techniques are categorized in terms of actuarial, observational, and interactive methods. The actuarial method utilizes historical records and establishes past frequencies of occurrence. The basic difference between the observational and interactive methods is whether there is direct interaction with the drivers who are being observed. The latter case usually involves some type of interview or questionnaire.

In the notes that were developed for a short course dealing with traffic performance data collection(7), the observational methods are discussed in terms of manual, photographic, semi-automatic and automatic measurement techniques. Table 4 summarizes the resources, applicability, advantages, and disadvantages of each technique as is indicated in that reference.

The "Procedural Guide for Highway Safety Engineering Studies"(8) also presents a discussion of field data collection techniques. In this publication, however, the methods are categorized as manual and photographic with the photographic method being subdivided into ground level and aerial surveillance methods. The manual method involves the use of trained personnel to make visual oberservations and inspections at the study site while the photographic method utilizes photograph equipment to record the physical and traffic conditions. The main difference between the ground level and the aerial surveillance methods is that the aerial surveillance method utilizes an aircraft for a filming platform at the study site. Table 5 summarizes the primary considerations associated with each of the techniques. A comparison of the utility of each of the techniques is also made and is shown in Table 6 while the applicability of each of the techniques to different roadway

TABLE 4

SUMMARY OF SELECTION FACTORS (7)

SELECTION FACTORS MANUAL	
RESOURCES	OBSERVER(S) DATA COLLECTION FORMS - STANDARD/TAILORED MECHANICAL COUNT BOARDS STOPWATCHES
TYPICAL MEASURES	BRAKE LIGHT APPLICATIONS COMPLIANCE WITH TRAFFIC CONTROL DEVICES TRAVELTIME AND DELAY ENCROACHMENTS ERRATIC MANEUVERS HEAD-TURNING MOVEMENTS LANE CHANGES/MERGES SPOT SPEED TRAFFIC CONFLICTS VEHICLE COUNT/CLASSIFICATION/ORIGIN/OCCUPANCY "OTHERS" - PHYSICAL EVIDENCE OF ERRORS
ADVANTAGES (POTENTIAL)	LOW COST MINIMAL EQUIPMENT MINIMAL DATA REDUCTION EASE OF USE - LOW VOLUME FEASIBLE UNDER MOST AMBIENT CONDITIONS
DISADVANTAGES (POTENTIAL)	LABOR INTENSIVE QUESTIONABLE RELIABILITY/ACCURACY PERSONNEL TRAINING/QUALITY CONTROL VOLUME SENSITIVE OBTRUSIVENESS VANTAGE CRITICAL

TABLE 4 (Continued)

SUMMARY OF SELECTION FACTORS (7)

SELECTION FACTORS PHOTOGRAPHIC	
TECHNIQUES	REAL-TIME FILM OR VIDEO TIME-LAPSE FILM OR VIDEO STILL AERIAL
RESOURCES	OPERATOR CAMERA/LENS SYSTEM FILM/VIDEO TAPE
TYPICAL MEASURES	PERMANENT RECORD MINIMAL FIELD PERSONNEL MODERATE DATA COLLECTION COSTS ENHANCED ACURACY/RELIABILITY/EFFICIENCY USABLE WITH HIGH VOLUME
ADVANTAGES (POTENTIAL)	PERMANENT RECORD MINIMAL FIELD PERSONNEL MODERATE DATA COLLECTION COSTS ENHANCED ACCURACY/RELIABILITY/EFFICIENCY USABLE WITH HIGH VOLUME
DISADVANTAGES (POTENTIAL)	ARDUOUS, EXPENSIVE DATA REDUCTION VANTAGE/FIELD OF VIEW CRICTICAL INEFFICIENT WITH LOW VOLUME/RARE EVENTS AFFECTED BY AMBIENT CONDITIONS PROCESSING DELAY (FILM) FORMAT, RATE, FILM SPEED, RESOLUTION CRITICAL

TABLE 4 (Continued)

SUMMARY OF SELECTION FACTORS (7)

SELECTION FACTORS	SEMI-AUTOMATIC
RESOURCES	OBSERVERS/OPERATORS ELECTRONIC STOPWATCHES ELECTRONIC COUNT BOARDS RADAR METERS SUPPLEMENTAL FORMS
TYPICAL MEASURES	ALL MEASURES THAT CAN BE COLLECTED MANUALLY
ADVANTAGES (POTENTIAL)	MODERATE COST ENHANCED ACCURACY/RELIABILITY/EFFICIENCY MINIMAL DATA REDUCTION
DISADVANTAGES (POTENTIAL)	TRAINING REQUIRED EQUIPMENT MALFUNCTIONS POWER SOURCE REQUIRED OBTRUSIVENESS - DETECTION VANTAGE CRITICAL

TABLE 4 (Continued)

SUMMARY OF SELECTION FACTORS (7)

SELECTION FACTORS	
	AUTOMATIC
RESOURCES	OPERATOR SENSOR/DETECTOR TRAFFIC COUNTERS/CLASSIFIERS/ANALYZERS SPEED CLASSIFIERS EVENT RECORDERS/TRAVEL TIME COUNTERS FUEL FLOW METERS DATA LINKS/PROCESSORS
TYPICAL MEASURES	TRAVELTIME AND DELAY ENCROACHMENTS FUEL CONSUMPTION LATERAL PLACEMENT SPOT SPEED AND SPEED PROFILE TIME HEADWAY TIME THROUGH INTERSECTION VEHICLE COUNT/CLASSIFICATION VOLUME WEIGH-IN-MOTION
ADVANTAGES (POTENTIAL)	MINIMUM PERSONNEL PERMANENT RECORD NOT VOLUME SENSITIVE HIGH DATA ACCURACY/RELIABILITY UNOBTRUSIVE EQUIPMENT EFFICIENT DATA COLLECTION - MULTIPLE MEASURES AUTOMATED DATA REDUCTION AUTOMATED DATA LINK
DISADVANTAGES (POTENTIAL)	HIGH COST HIGH-LEVEL PERSONNEL SENSOR/DETECTOR OBTRUSIVENESS EQUIPMENT/SENSOR MALFUNCTIONS POWER SOURCE REQUIRED DATA PROCESSING INCOMPATABILITIES

TABLE 5

PRIMARY CONSIDERATIONS FOR STUDY TECHNIQUES (8)

		CONSIDERATIONS						
Technique	Function	Equipment Requirements	Manpower Requirements	Time Requirements	Associated Costs	Data Input	Data Obtained	Data Output
1. Field Method	Observe highway facilities and traffic flow in the field environment	• Pencils • Data forms	• Traffic Engineer or or highly trained technician to observe location	• Observation time (as provided in Table 7)	None	• Identified hazardous location • Accident studies • Past field reports • Past records of location • Citizen input	• Observation or inspection of all operational and physical site data	• Identification of possible operational and physical (environment) site deficiencies
2. Photographic Technique -Ground Method	Observe highway facilities and traffic operations under field conditions in an office environment	• Camera equipment • Film screen • Data forms	• Camera technician to set up and remove camera(s) • Technician to spot check camera (for longer observation periods) • Traffic engineer or highly trained technician to observe location	• Camera set up and removal time ranges from 1-3 hours per camera dependent on travel time involved	Camera equipment $500 - $2,000	• Identified hazardous location • Accident studies • Past field reports • Past records of location • Citizen input	• Observation from film or operational and physical site data item (excludes those physical items outside adequate camera range) • Other traffic data (gap, volume, etc.)	• Identification of possible operational and some physical (environment) site deficiencies
Photographic Technique Aerial Surveillance	Observe highway facilities and traffic flow under field operations in an office environment	• Airplane or helicopter availability • Camera equipment • Pencils • Data forms • Film screen	• Pilot • Camera technician to set up and check camera • Traffic engineer or highly trained technician to review film data (operations)	• Air time • Observation time	Subcontract filming rates $150 per site	• Identified hazardous location • Accident studies • Past field reports • Past records of location • Citizen input	• Identification of operational and physical (environment) site data	• Identification of possible operational and physical (environment) site deficiencies

TABLE 6

STUDY TECHNIQUE UTILITY[8]

	STUDY TECHNIQUE		
		PHOTOGRAPHIC TECHNIQUE	
Management Concern	Field Method	Ground Level Method	Aerial Surveillance
Manpower Requirements	* Traffic engineer or trained technician for field review	* Traffic engineer to view film and field review physical characteristics * Trained technician for camera set-up	* Traffic engineer to view film * Trained technician or traffic engineer for field review of physical characteristics
Equipment Requirements	* Minimal	* Camera equipment	* Airplane or helicopter availability * Camera equipment
Time Requirements	* Usually limited to two hours or less (due to human limitations)	* Able to use over extended period of time	* Limited by flying time of airplane or helicopter
COMPREHENSIVENESS OF INFORMATION			
- Operation-Related	* Provides detailed review	* Provides detailed review (limited by camera perspective)	* Provides general review
- Physical Roadway Elements	* Provides detailed review	* Requires separate field review	* Requires separate field review

situations is shown in Table 7. For each of the traffic based study procedures contained in the Procedural Guide, there is a discussion of the primary considerations for each study type, the utility of each of the techniques, and the application of the each of the techniques to specific situations. For example, Tables 8, 9, and 10 summarize this information for a volume study.

In 1983, Lyles and Wyman[9] published a paper which reviewed automated data collection systems. Generally, the focus of their work was on the utilization of automatic vehicle classification systems which provides for the collection of vehicle classification and speed data.

While studies have been refined and improved over the years, there is little evidence of new studies or study techniques. A similar statement could be made in terms of equipment in that there has been an evolution in the equipment which reflects technical improvements and refinements in study equipment.

Even the photographic field data collection methods have been in use for a considerable period of time. Greenshields[10] suggested the use of time-motion pictures for studying traffic behavior in 1933. This photographic method was later used by Greenshields et.al.[11] in studies of traffic performance at urban intersections. The results of this particular research effort has been widely utilized by highway and traffic engineers. Rice[12] reported on the use of aerial photography in the study of traffic operations in 1963. In that work, a helicopter was used in connection with photographic studies of traffic problem locations in the Washington, D. C. area.

In the early 1970's, there was considerable emphasis on the use of

TABLE 7

TECHNIQUE APPLICABILITY TO ROADWAY SITUATIONS (8)

Situation	STUDY TECHNIQUE		
	Field Method	PHOTOGRAPHIC TECHNIQUE	
		Ground Method	Aerial Surveillance
Intersection or Spot Location	X	X	
Roadway Segment or Link	X	X	
Corridor			X
Interchange	X	X	X

TABLE 8

PRIMARY CONSIDERATIONS FOR VOLUME STUDY TECHNIQUES(8)

Technique	Function	CONSIDERATIONS: Equipment Requirements	Manpower Requirements	Time Requirements	Associated Costs	Data Input	Data Obtained	Data Output
A. Mechanical Counters								
1. Permanent	Records continuous count data at fixed locations	• Counting device (normally installed at individual locations as part of a systemwide program) • Recording device • Miscellaneous maintenance equipment	• After installation of counters, an experienced technician is necessary for maintenance purposes	• Installation time per counter ranges (from 4-8 hours) • Data recording or analysis time is minimal	• Counter and installation (dependent on type selected) $1,500-$10,000	• Specific location	• Continuous volume count, speed, and other traffic data	• Volume, speed, and other related traffic data
2. Portable	Records short-term, periodic counts at a flexible list of locations	• Traffic counter (junior, period, or senior) • Pneumatic road tubing, cable sensors or tape-switch	• Two technicians to install counters (one person to install counter, other person to alert traffic to their presence) • A technician or engineer to record or adjust counts	• Installation time ranges from 15 minutes to one hour per counter, dependent on travel time, number of counters installed, and maintenance of counter • Data recording time is minor (approx. 15 min per 24 hr count)	• Initial cost of counter, tubing, hammer, nails, etc. $850-$2,000	• Specific location	• Specific volume count data (in some cases, speed and other related traffic data)	• Volume data
B. Manual Counts	Records short-term volume data with the use of field observers	• Counting board or hand counter • Pencils • Data sheets • Calculator	• Dependent on volume of traffic and tally equipment used • Manpower requirements range from one to four technicians • Technician or engineer to sum or adjust counts	• Time spent in obtaining data varies with period of count	• Initial cost of counting boards ranges from $125 (single counter) to $450 (four counter board)	• Specific location	• Specific volume count data	• Volume data
C. Moving Vehicle Method	Records directional volume data (and speed and travel-time data) along roadway segments while transversing the roadway section	• Vehicle • Counting board or hand counter • Time recording device or analyser • Pencils • Data sheets • Calculator	• A driver (technician) • A minimum of one recorder (dependent on traffic volumes and availability of time recording devices) • Engineer to compute volume and other data	• A minimum of six test runs per direction is recommended • Duration of test runs is dependent on length of test section and time of day (peak or off-peak period) • Data analysis requires approximately one-half hour per section	• Initial cost of recording device or traffic analyzer (dependent on capabilities) and miscellaneous maintenance equipment $1,000-$3,000	• Specific location	• Travel time, opposing traffic, overtaking traffic, and passed traffic data	• Travel time, travel speed, and volume data
D. Photographic Techniques	Records volume data (and other stream flow data characteristics) from photographic records	• Camera • Time-lapse mechanism • Airplane availability (dependent on technique used) • Counting board or hand tally • Calulator	• A person experienced in photographic set-up procedures • A technician to check equipment during operation • A trained technician or engineer to view and record data • With aerial photography pilot and experienced engineer to calculate data is required	• Camera set-up time is approximately one-half hour • Technician check of equipment varies with distance of location of office (ranges approximately from 10 min to an hour) • Data review and analysis time is related to period of actual count	• Initial cost of camera equipment (dependent on quality) $500-$2,000	• Specific location	• Speed, volume, vehicle classification, spacing between vehicles, and vehicle movement (turn) patterns	• Speed, volume, and other traffic data

TABLE 9

TECHNIQUE UTILITY FOR VOLUME STUDY(8)

Management Concern	STUDY TECHNIQUE				
	MECHANICAL		Manual	Moving Vehicle Method	Photographic Techniques
	Permanent	Portable			
1. Time Requirements	Continuous long-term counting	Flexible counting periods (limited by battery life)	Usually limited to to a period of two hours or less	Short term (one hour or less)	Short term in nature (several days maximum)
2. Manpower Requirements	Technician level	Technician level	Technician level	Technician level	Technician level
3. Equipment Requirements	Permanent detector Installation	Portable counter	Minimal	Vehicle availability	Camera equipment Airplane availability (aerial)
4. Information Needs *Intersection Volumes	Typically by approach	Typically by approach	By lane use or specific movement	Not practical	By lane use or specific movement
*Mid-Block Volumes	By direction (where installed)	By direction	By direction	By direction	By direction
*Pedestrian Volumes	Not practical for highway safety applications	Not practical for highway safety applications	Provides an accurate record	Not applicable	Reasonable for use when studying pedestrian behavior characteristics
*Classification Studies	Not all equipment applicable	Not all equipment applicable	Provides an accurate record	Provides an estimate	Can provide an accurate record
5. Level of Accuracy	Accurate	Accurate	Highly accurate	Estimate	Estimate

TABLE 10

FAVORABLE VOLUME STUDY TECHNIQUES(8)

Information Type	STUDY TECHNIQUE: MECHANICAL Permanent	MECHANICAL Portable	Manual	Moving Vehicle Method	Photographic Technique
Annual Total Traffic	X				
AADT or ADT	X	X			
Peak Hour					
- Mid-Block	X	X	X	X	X
- Intersection	X	X	X		X
Short Term					
- Mid-Block	X	X	X		X
- Intersection	X	X	X		X
Classification Counts			X		X
Pedestrian Volumes			X		X

photograph and optical instrumentation in the study of highway and traffic engineering problems. Two conferences were specifically devoted to this area with the first being held in California in 1971, and the second in Washington, D. C. in 1973. The papers from these conferences were later published in the Proceedings of Society of the Photo-optical Instrumentation Engineers[13,14]. Basically, the conferences focused on the use of photologging as well as the application of time-lapse and video methods in highway and traffic engineering studies.

These two proceedings contain a number of papers which are pertinent to the problem of intersection data collection and the application of photographic and television equipment in field studies. For example, Wasser[15] discussed the use of time-lapse photography in the solution of traffic problems. He identified the use in terms of (a) traffic problems, (b) public relations problems, and (c) non-problems. The area of traffic problems deals with field studies that are related to a problem. Public relations applications are associated with the use of this type of equipment to show the effects of improvements to public groups. Finally, the non-problem area represents the use of the time-lapse camera to give public officials first hand viewing of locations about which complaints may have been received. In this case, Wasser suggests that the films may be used to demonstrate that a problem really does not exist.

A paper by Baker and Williams[16] describes their experience with utilizing time-lapse television equipment for traffic studies. The intent of this work was determine if time-lapse television could be used for traffic analyses.

The work by Mosher[17] involved the development of a system which used aerial and ground photographic equipment. This research was associated with the study traffic flow on freeways and the effects of exit ramps on freeway operation and control.

Treiterer[18] discussed several photographic techniques that may be used in the study of intersections. These techniques included the use of:

a) a rotating camera,

b) a split-image camera,

c) two cameras mounted on opposite corners of an intersection, and

d) aerial cameras mounted in a helicopter.

In the first two techniques, the camera was suspended over the center of the intersection. Further discussion of the first two techniques is also found in the paper by Nemeth and Treiterer[19]. Also, the use of the split image camera in the collection of intersection data is described by Diewald and Nemeth[20]. All of this work was accomplished in the late 1960's as part of a project which focused on the development of new intersection study techniques.

Kuperstein and Li[21] prepared a paper which described their experiences in using photographic methods in connection with one study involving intersections and a second study where instantaneous surveys of a one-half square mile study area were necessary. In the first study, time-lapse photographs of an intersection were used while the second study employed aerial photographs taken from an aircraft.

Murphy[22] used photographic methods to count and classify vehicles on a low volume road. In this system, a picture of the vehicle was taken when a vehicle was detected.

The application of time-lapse photographic equipment is presented in a paper by Weaver[23]. In this paper, the uses in California and types of equipment are discussed. It is interesting to note that Weaver concludes that time-lapse photographic equipment offers an almost ideal solution to many problems for the traffic engineer with limited staff and budget.

Because of the limitations in the field of view of cameras, many study locations may require the use of more than one camera. In the studies undertaken by Cribbins[24], multiple cameras were used in collecting data at an intersection. For this study, several movie cameras were interconnected which permitted simultaneous filming.

In 1975, a report[25] which outlined the use of time-lapse photography was prepared for the Federal Highway Administration. This report generally reviewed the use and application of time-lapse photography as well as the analysis of the film.

More recently, a data collection manual was prepared as part of a research effort involving the study of traffic signal yellow intervals[26]. While the specific focus of the manual is related to the collection of data that are pertinent to the timing of the yellow interval, there is an extensive discussion of the use of the time-lapse camera equipment. This discussion includes the design of the field study, the location and operation of the photographic equipment, as well as the reduction of the data from the film record.

Certainly, the literature contains other studies which have utilized photography or television for data collection purposes. The emphasis in many of the studies, however, is not on the advantages and disadvantages of the equipment.

CURRENT ORGANIZATIONAL PRACTICES

Because of previous interaction with many of the traffic and transportation agencies in Arizona, the research group had a reasonable degree of understanding of the current practices which are related to field studies and data collection. To supplement this information, however, a series of interviews were conducted with selected employees of city, county, and state agencies. The interviews were not designed to be a statistical sample of highway and traffic orgainzations, but rather were aimed at establishing the nature of and problems with field studies and data collection.

In the interviews, questions focused on the following areas:

a) the availability of study equipment,

b) desired study equipment that is not available,

c) personnel resources for field studies and invesitigations,

d) types of studies that are conducted,

e) types of data that are obtained on a regular basis and by special studies, and

f) general problems associated with data collection.

The discussion which follows summarizes the findings and situation in each of these areas.

AVAILABLE STUDY EQUIPMENT

Generally, the equipment that is available in agencies at all levels of operation is somewhat limited in both type and quantity. In most cases, the types of equipment are limited to what would be considered as basic field study equipment such as include traffic volume counters, manual turn movement count boards, stop watches, still cameras, and radar meters. In some cases, the equipment is not immediately accessible to a specific individual in that it must be borrowed from another group or office in the organization. These arrangements could take time; thus it limits the accessibility to that particular piece of equipment.

The availablility of study equipment such as electronic turn movement count boards, time-lapse cameras, and portable television units is extremely limited. While there are organizations in Arizona that do have this type of equipment, it is not commonly found. It should be noted that no organization in Arizona was found that had the complete inventory of the types of field study equipment that are currently available on the market.

DESIRED EQUIPMENT

Because of the nature of the response to the equipment that is available, the indication of desired equipment varied considerably. For example, if an individual did not have the more common types of study equipment available, then the desired equipment would be a traffic counter, a manual intersection turn movement count board, or even a radar speed meter. In some cases, the responses were associated with the need to have the equipment available rather than to have to make arrangements for the use of such equipment with others within an organization. There is a recognition that time-lapse cameras or portable television recorders could be beneficial; thus there is a desire for this type of equipment. At the same time, budget limitations were frequently cited as the reason for the lack of desired equipment.

PERSONNEL RESOURCES

In all of the organizations for which information was obtained, the limitations on available personnel pose restrictions on field investigations and data collection. These limitations exist both in terms of engineering level personnel as well as technicians who may be used for these activities. Regardless of the overall size of the organization, the conduct of traffic studies which require more than a few individuals for data collection is a problem. In essence, personnel resources is a major concern when considering data collection.

The time availability of employees during a day also presents some restrictions on field studies. The practices of compensating employees for work at times other than the normal work day will vary with the policy of an organization. If it is necessary to pay overtime for work outside of the normal work hours, then the field studies may be restricted by budgeted funds. On the other hand, some organizations utilize flexible work hours or give the employee compensatory time. Because of the nature of traffic problems and the need to collect data at times other than the normal work day, the time availability question must be considered.

In addition, the limitations on available personnel apparently dictates the manner in which an organization identifies and addresses traffic problems. For most cases, organizations operate in what could be considered a "response" mode of operation. In this type of operation, field studies are generally undertaken in response to complaints or requests for some type of data. Because of the number of complaints or requests, organizations are continually placed in a position of responding to these situations. It is not common for an organization to have an opportunity to undertake studies of a preventive nature whereby potential problems are detected in early stages. Some organizations have senior personnel drive assigned routes in their travel to and from work. In this way, these individuals observe the traffic flow and operations on that route and report problems or deficiencies that should be investigated. Certainly, this does provide input based on the observations of individuals who do have pertinent training and should be able to detect problems or even potential problems. This type of activity is generally limited to the major arterial system and is a function of the policies of the organization in terms of the use of vehicles.

TYPES OF STUDIES

The types of studies which have been undertaken in the past have generally been associated with traffic signals and accident analyses. It is common for studies to be undertaken to evaluate signal warrants or to assess signal or intersection design. For these situations, the main focus is on appraoch volumes and turn movement volumes. For accident analyses, accident information is obtained from the records data base; however it is frequently necessary to establish the physical features of the intersection and an inventory of the traffic control devices. In addition, site inspections of the intersections under study are made in an attempt to identify the cause of the accidents. At the time of the field inspection, personnel may record specific data based on their observations. Because of the limits on time and personnel, the site investigations frequently must rely on the experience and judgment of an individual with respect to the observations that are made. In many cases, it is not possible to make field studies according to established field study procedures.

Certainly, many other types of studies are undertaken such as delay, pedestrian, vehicle classification, travel time, queue length, etc. These studies, however, are much less frequent than those mentioned previously.

TYPES OF DATA COLLECTED

Basically, the data which are collected on a somewhat regular basis includes volume, accident, and inventory information. Generally, the volume data is associated with approach counts which may be made in connection with a volume counting program. Because of the fact that the investigation of problems is generally on a responsive basis, other types of data are acquired in response to a particular need. Again, it should be noted that the interest in this study is with intersections. Organizations do collect other types of data on a regular basis; however that data may not be pertinent to intersections.

GENERAL PROBLEMS

In the preceeding discussion, a number of problems associated with the field studies and data collection have been indicated. These included equipment and personnel limitations. While somewhat related to the question of available resources, several of the individuals interviewed cited travel time to some of the intersection locations as being a problem. Because of the size of the area under the responsibility of a jurisdiction, travel to some of the more remote locations consumes a considerable amount of time in relation to the time spent at a study location. Because of the size of a jurisdiction, some intersections may operate for extended periods of time without being visited by senior level personnel. While the spatial magnitude of a jurisdiction is not as great a problem for cities, it is significant in terms of state and county operations. In this respect, engineers must frequently rely on others for reporting problems at a given location. In essence, the size of jurisdictions in Arizona and resulting travel times to the intersection locations presents logistical concerns which must be addressed when investigating traffic problems and collecting field data.

ANALYSIS AND EVALUATION OF STUDY METHODS

There are many references that describe engineering and scientific problem solving including the steps in the process. Data collection or the acquisition of information is normally shown as one of the steps which must be accomplished; and the level of effort in this step must be consistent with that devoted to the overall problem solving process. For example, a massive and time consuming data collection effort would be inconsistent with situation where a quick and rough estimate is needed.

Furthermore, one of the key considerations in a problem solving exercise is the definition and allocation of the available resources. Generally, the resources are defined in terms of monetary and time requirements. Basically, it is necessary to identify how much money will be expended on the investigation and evaluation of the problem and how much time is available for accomplishing the effort. The definition of the available resources serves to establish the overall level of effort that will be applied to addressing the problem.

The inclusion of the monetary consideration inherently includes the question of personnel. This implies that there is some degree of flexibility in managing the number of personnel who are assigned to a project. It might be argued, however, that this situation does not exist in organizations where there are constraints on the number of available personnel and there is little or no opportunity for temporary additions to the staff. In this case, the resource constraint could be the number of available employees rather than a monetary limit per se.

The solution of traffic problems at intersections is certainly no exception to the rule with respect to the problem solving process. The burden is on the highway or traffic engineer to establish the investigation that is necessary for the solution to the problem within the available resources. Field studies and data collection must be undertaken as necessary to assist in the analysis of the problem. Suitable methods or techniques must also be selected for the field studies and data collection.

The overall listing of studies and information that are pertinent to the operational and design analysis of an intersection can be quite extensive. Such a list would include the following types of studies and information:

a) approach volumes
b) turn movement volumes
c) vehicle classification
d) approach speeds
e) vehicle gaps and headways
f) conflicts
g) observance and compliance
h) capacity analysis
i) saturation flow
j) driver response time
k) pedestrian
l) signal operation
m) transit operations
n) acceleration and deceleration rates
o) saturation flow
p) delay (including stop time and total delay)
q) erratic maneuvers
r) vehicle arrivals
s) lane change
t) queue length
u) vehicle discharge
v) gap acceptance
w) physical inventory

x) lane utilization and occupancy
y) signal timing utilization

Obviously, for a given problem or situation, it is unlikely that all of this information would be needed; thus it would be necessary to select the pertinent types of information or data that are appropriate.

References, such as the Manual of Traffic Engineering Studies, outline the procedures for the conduct of the field studies and data collection. These procedures are designed to aid the highway or traffic engineer in the data collection and give some assurance that the necessary information is collected and recorded. Where the data collection involves taking a selected sample, the procedures are designed so that a statistically reliable sample is obtained for analysis purposes. In essence, some given level of reliablity is assumed if the procedures are followed. While established procedures do exist, an engineer must assess the applicability and reliablity of the approach that is to be taken for the data collection.

Certainly, the data collection problem is a bit different in situations where the focus is on the cause of a problem in constrast to one in which the interest is in measuring the effect of some type of change at an intersection. In the first case, the engineer may not exactly know the specific types of data that are needed to assess the situation. For such cases, engineers will frequently observe the site for a period of time to try to identify the causes of problems and the types of data that are required. In the latter situation, an appropriate measure of effectiveness should be selected which will aid in the evaluation. The measure of effectiveness would also be pertinent when considering alternative solutions to a problem. The measure or measures of effectiveness, therefore, become the criteria by which the alternatives are evaluated.

STUDY METHOD AND TECHNIQUE SELECTION FACTORS

A number of factors can be identified which should be considered in selection of field study method or techniques. While the interest in this research is associated with intersection related studies, these factors would also be applicable to other types of highway and traffic field studies. The selection factors would include:

a) equipment availability,
b) personnel availability,
c) staff exerience and training,
d) cost (including field study and data reduction),
e) time requirements,
f) accuracy and reliability of the method,
g) use of the data or information, and
h) location conditions.

In some cases, comments which are pertinent to each of these factors have already been made in previous sections. The discussion which follows summarizes the concerns and considerations associated with each of the factors.

Equipment Availability

The availablility or even the accessibility of equipment is a rather obvious consideration when selecting a field study or data collection method. As was indicated in the review of current practice in Arizona, this factor does pose a real constraint and is a major consideration. The significance or importance of the factor diminishes with an increase in the available inventory of types of equipment.

Personnel Availability

Again, this appears to be a significant factor based on the review of the current situation in Arizona. Organizations generally have a very limited number of people who can be devoted to field studies on a regular basis. A study that could be considered to be labor intensive is frequently not possible because of the limits on available personnel. At the same time, the utilization of engineering level personnel must be considered in making field investigations. Some field study methods offer the advantage of making a visual record of the conditions at a site which may later be reviewed in the office. Such a method potentially reduces the time for the engineering level personnel for review the operation of an intersection because some of the need for an actual site visit may be eliminated.

Staff Experience and Training

Familiarity and experience with equipment and procedures plays an important role in successful data collection efforts. In using some new procedure or equipment, a certain period of learning is normally necessary before the expected results can be expected. As the engineering as well as the technician level staff gains experience with the full range of available techniques and equipment, the alternatives for study method are broadened. The need for experience and training certainly becomes more important with study equipment that is more complex to operate. Not only is knowledge about the operation of the equipment vital, the operator frequently must have experience in applying the equipment to some situation if the field data are to be useful. This is particularly important with photographic and television methods where experience in filming or taping conditions at an intersection can make a significant difference in the quality of the visual record. The importance of experience is expressed by Berger and Sanders(25) in the epilogue of the publication which deals with guidelines for the use of time-lapse photography. They note that first hand experience is the best, and only, way to make sure that field studies turn out as expected.

Cost

In virtually any operation, cost is a concern; and there should be a desire to find the most economical method of acquiring the required data. Where a method relies upon specific types of equipment, the initial purchase price and annual maintenance costs are to be considered. Normally, equipment is used over a several year period and is not charged to a specific project. In situations where a piece of equipment is widely used, the cost for a specific study may be quite small.

Other elements in this selection factor include the costs associated with the actual field study as well as the data reduction time. While most studies require some type of summarization of the field data collection, data reduction time for the photographic and video methods is significant. On the other hand, such methods have an inherent advantage of reducing the number of personnel that is required for field data collection. Given the time and distance to some of the intersection locations in a jurisdiction, the reduction of field personnel requirements can offset the data reduction time. The time required for data reduction is further discussed in a later section.

Time Requirements

There are several aspects to the time requirement factor. First, the overall time available for the conduct of the study is an initial consideration. Basically, the question in this case is related to how soon an answer to the problem is needed. Delays in processing the field data may require too much time for the problem at hand.

The time duration of a study might be a second consideration. Certainly, for studies that require data at a given site over a longer period of time, it is reasonable to attempt to use equipment that can be left unattended at the site. Generally, the use of equipment that would need frequent or constant attention would not be desirable.

Finally, the time of day of the study may be an important factor. Because of safety and security problems, nighttime studies involving staff at the study site may present a problem. In addition, the availability of personnel at times other than the normal work day may influence the decisions relative to study methods. Some study methods have inherent restrictions which prevent their use at night. For example, photographic and television normally requires daylight conditions or artificial lighting. In order to overcome this constraint, Wortman and Matthias[27,28] used high speed film in a time-lapse camera. This enabled them to record the vehicle lights on the film during the hours of darkness.

Accuracy and Reliability

Normally, questions related to the accuracy and reliablility of data are related to the precision of the measurement or the possible error in the sampling process. These are important aspects of this selection factor. In data collection, however, an equally important consideration is the validation of a data set if there are any questions. For example, data collected using field observers is sometimes recorded in a manner that makes its use questionable. In such cases, one must decide if it is necessary to repeat the study. Sometimes it may not be possible to repeat a study if conditions have changed.

The use of equipment for data collection does not eliminate the problem. There is always a risk that the equipment will malfunction; thus the data sample will be lost. While the photographic record of traffic characteristics at an intersection will permit the validation of data, there is the possiblity that the camera will malfunction without the operator being aware of the problem.

Use of Data or Information

As has been indicated previously, field data collection may be undertaken in response to a need for a specific type of data. In this case, the data requirements may be well defined; and a study method can be selected based on the most economical and convenient technique that is available. On the other hand, in situations where the cause of a problem is being investigated, the types of data that are required may not actually be known. The responsible individual must either anticipate the data requirements or possibly undertake some preliminary investigations to try to identify the data to be collected. Methods, such as photography, which enable the engineer to obtain a record of multiple operational characteristics may be advantageous in that acquisition of an additional data type may be possible without having to return to the site for further field studies.

Location Conditions

The location conditions are related to the traffic conditions at the study site, questions of personnel safety, and site conditions which may influence or restrict data collection alternatives. At locations where heavy traffic volumes exist, study methods which may disrupt traffic flow during the installation of study equipment or the conduct of the study may be undesirable. The question of safety is somewhat related in that the necessity for the presence of personnel in the street or near the intersection is a potential safety problem. Methods which minimize the need for and number of personnel in or near the roadway have safety advantages.

The physical layout and the surrounding environment at an intersection site may restrict the data collection alternatives. For example, photographic and television methods generally require some type of elevated location for the equipment. At some locations, it may be difficult to find a suitable location or even a place to park a vehicle with an elevating platform; thus it may not be feasible to consider such methods.

FIELD STUDY EVALUATION

For the more commonly used field study equipment, highway and traffic engineers have extensive experience in its application to data collection problems. In addition, the literature contains discussions on the use of this equipment and the expected results. Photographic and television equipment is not commonly available to highway and traffic engineers, and many have had little or no experience with such equipment. Furthermore, the literature is not as specific in terms of some of the applications and comparisons which may be made. While statements are made regarding the possible use of such equipment for a particular type of data collection, the statements tend to be of a general nature. The evaluation undertaken as part of this project, therefore, focused on work which would better define the capabilities of the photographic and television equipment as well as compare the capabilities with other approaches to data collection.

Time-lapse Photography Versus Television

One of the initial questions which arises when considering the use of a visual record of traffic operations at a location is whether to use time lapse-photography or television. Obviously, there has been many advancements in recent years in the technology that is associated with video recorders. In fact, the sales of video equipment to the general public has had a definite impact on the demand for and availability of super 8 mm movie equipment. At the same time, the cost of telvision equipment has generally decreased while the capabilities of the equipment have been enhanced.

Certainly, there have been advances in the time-lapse photography equipment as well. For early studies, engineers had to build an intervalometer which enabled them to photograph conditions at set intervals. The development of digital controls has improved the operation of the camera and the accuracy of the photographic record. While early studies generally used 16 mm movie cameras, the commonly used equipment for traffic studies is a super 8 mm camera with a zoom lens. The main advantages of the super 8 mm equipment over the 16 mm cameras are associated with the cost and availability of the film.

When considering photographic or television equipment, an initial concern is the cost of the systems. The commonly used super 8 mm time-lapse photographic system will cost in the range of $4300 to $6000. The variation in cost is associated with the capabilities of the camera and the projector such as imposing the time of the photograph on the film and the addition of a frame counter on the projector.

The cost of television equipment will also vary with the capabilities of the equipment. Recent advertisements indicate the availability of a color video camera with a built in recorder for approximately $1600. This unit has the capability of recording for periods of up to 20 minutes. Other portable units with recording capabilities of up to eight hours can be obtained for approximately $2000. For viewing the video tapes, a monitor would also be necessary. Normally, the cost of a monitor would be in the range of $400 to $600. These prices, however, reflect the costs of units that are available on the general commercial market. While it would appear that the initial cost of a television system is somewhat less than the super 8 mm movie system, the capabilities of the two systems are somewhat different. For example, the video recording would not have a time reference on the tape. This time reference is important where time measurements are a necessary part of the data collection. In addition, it is not always possible to speed up or slow down the video recording without having interference in the picture. Video systems are available which would overcome these deficiencies; however the cost of the system would be increased to a level that is comparable with the movie system.

The maximum recording time is also a consideration. A roll of super 8 mm film contains approximately 3600 frames. The maximum duration is a function of the frame speed that is used. For traffic studies, commonly used frame speeds are one or two frames per second. At these frame speeds, a roll of film will run for periods of one hour and 30 minutes, respectively. In essence, the higher the frame speed, the shorter the duration of the filming period. Where studies require a more precise measurement of time, it may be necessary to operate the camera at even higher frame speeds.

Depending on the type of unit used, the video units have the capability for operating for much longer periods of time under a continuous operation without having to change the tape. In addition, it is possible to immediately check the video recording for adequacy of the visual record while it is necessary to have the movie film processed before it can be viewed.

The major difference in the visual record for the two systems is in the quality of the picture and the details which may be detected. Because of the design of the television system and a limit on the number of lines in projecting the picture, some of the details cannot be detected. Field tests were undertaken for the purpose of visually comparing the time-lapse films, color video, and black and white video recordings. An intersection was simultaneously filmed with the three systems. The results were viewed to determine clarity of the pictures, ease of use, and the level of detail that could be depicted. Certainly, the color video picture was much preferred over the black and white recording because of the clarity of the picture and the details that could be detected. The super 8 mm movie film provided a picture that was superior to the color video tape. Details such as brake lights and traffic signals are more readily visible on the projection of the movie film.

Generally, this comparison verified comments which others have made in the past about these different systems. Portable television systems can provide a visual record of the operation of an intersection with more restrictions on the level of detail than can be obtained with the movie film. Where time measurements are necessary as part of the data collection, the time-lapse photography equipment has an advantage.

Data Reduction Time

One of the main concerns associated with the photographic and television methods is the time required for data reduction. While such methods reduce the number of personnel required for the actual field study, it is necessary to then extract the needed information from the film or tape. In an attempt to quantify the time required for data reduction, an investigation was undertaken in which data were extracted from time-lapse films of intersections.

For this work, two commonly used types of traffic studies were selected for evaluation. These studies included the turn movement volume count and stop time delay. An inventory of films which could be used for this analysis were available as the result of other studies.

These films represented visual records from a variety of intersections with some variation in traffic volumes. In addition, some further field studies were undertaken for the purpose of obtaining films of specific types of intersections or experimenting with specific observation locations and camera operations. Using these films, pertinent data for each of these types of studies were recorded along with the time that was required to accomplish this work for each intersection.

For the volume study, it was found that a number of variables influenced the time required to extract the data. These variables were related both to the intersection as well as to the manner in which the intersection was filmed. The intersection variables included:

a) number of approach lanes,

b) traffic volume,

c) visual obstructions at the site,

d) signal phasing, and

e) approach speeds.

In terms of the operation of the camera, a number of variables were also noted which influenced the overall data reduction time. These included:

a) horizontal angle between the camera and the intersection approaches,

b) field of view,

c) frame speed, and

d) vertical angle between the camera and the intersection.

In filming an intersection, there is some control over the variables which are associated with the operation of the camera; and the influence of these variables can be minimized in some cases. For example, a volume count can be conducted using only one camera. It is relatively easy to obtain the information for the approaches which are parallel to the camera. The problem generally is with observing the cross street. Attempts were made to photograph the intersection with the camera located at 45 degrees with the approaches. This location represented an improvement if volumes on the approaches were approximately equal. If not, a location that is parallel to the heavier flow was preferable. In addition, the greater the field of view of the intersection approaches and an increase in the vertical angle between the camera and the intersection served to reduce the data reduction time. Finally, it was found that a frame speed of two frames per second was satisfactory for the volume study. A slower frame speed of one frame per second made it difficult to track the vehicles and increased the data reduction time.

The intersection variables generally are a function of the volume of traffic using the intersection; thus a relationship was found which estimates the data reduction time as a function of the volume of traffic. This relationship can be expressed by the following equation:

$$t = 7.78 + 0.015v$$

where

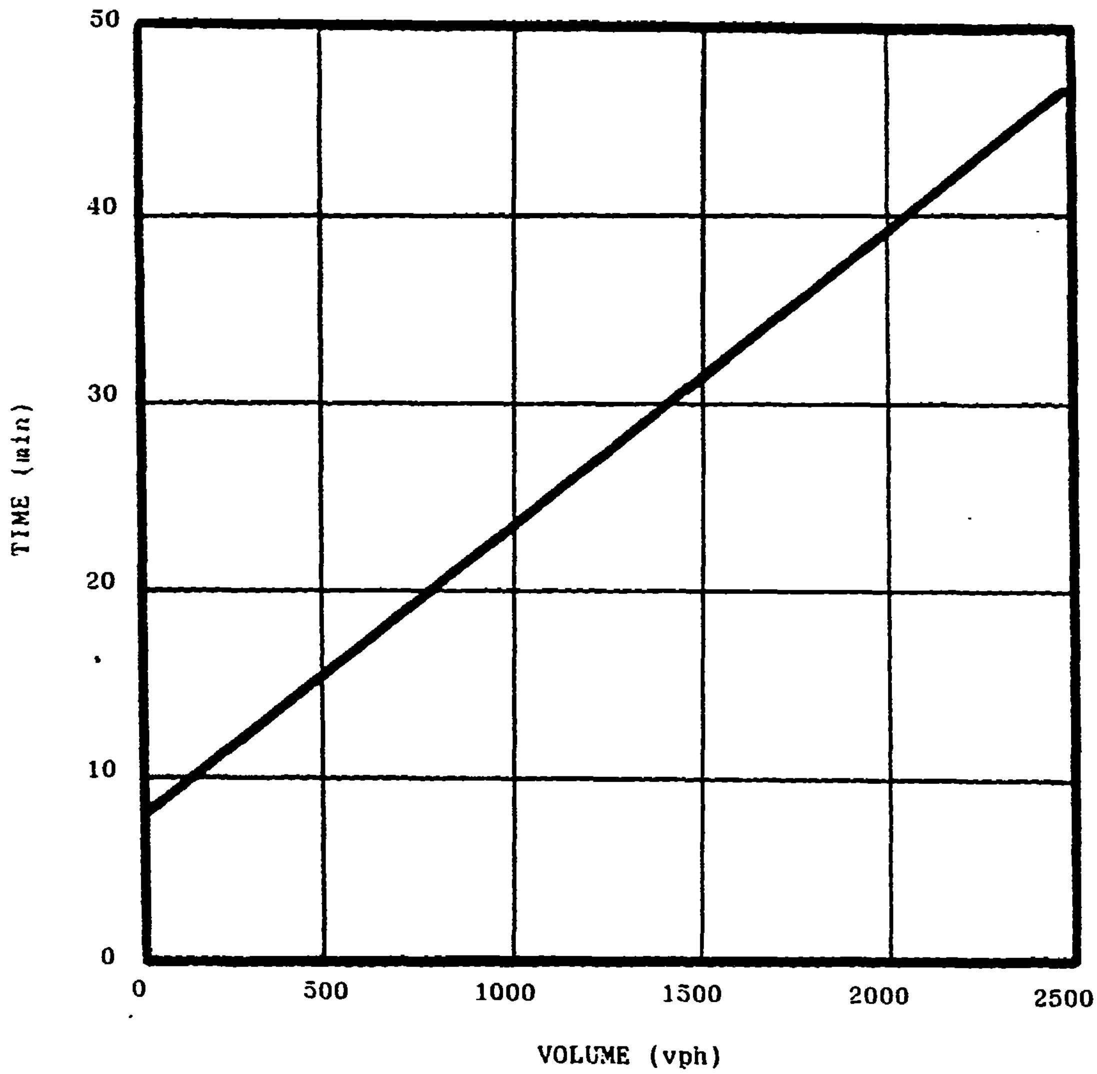
t = data reduction time in minutes, and

v = volume in vehicles per hour.

This relationship is graphically depicted in Figure 1. In essence, the data reduction time is much less than the actual field study time. In terms of personnel time, the photographic method can be advantageous if two people are used for the manual data collection in the field. The

FIGURE 1

ESTIMATED DATA REDUCTION TIME
FOR AN INTERSECTION VOLUME STUDY



photographic method would require only one person in the field for the volume study.

A similar relationship was found for the stop time delay study. In this case, however, the data reduction time is more related to the number of delayed vehicles rather than to the overall volume. This relationship was found to be as follows:

$$t = 36.7 + 0.02d$$

where

t = estimated data reduction time,

d = number of delayed vehicles.

It could be expected that the data reduction time for an entire intersection could be accomplished in about one to two hours. This would be quite advantageous over the manual method. Normally, a minimum of two persons per intersection approach are required for a manual stop time delay study; thus the study of an entire intersection would require a minimum of eight persons. This number could increase depending on the complexity of the intersection design.

It should be noted, however, that the field of view of a camera will usually restrict filming to only two approaches with one camera. It is necessary, therefore, to use more than one camera if the entire intersection is to be recorded at one time. With the current time-lapse photographic equipment, one person in the field could operate more than one camera.

For the delay study, it is possible to operate the camera at a slower frame speed. A speed of one frame per second was found to be satisfactory for this type of analysis. Some camera units can be programmed to take photograph several frames with set time periods between the series of photographs. Such an approach could also be utilized; however the filming of the intersection on a continuous basis over the period of the study provides a visual record for the duration of the study if other data are needed.

These evaluations indicate that the photographic methods do offer advantages in terms of potential time savings even when the data reduction time is considered. In addition, the number of personnel required when using such a method of data collection can be considerably less than for the manual methods of data collection. Finally, the data reduction is accomplished in an office where the working conditions are better controlled.

CONCLUSIONS AND RECOMMENDATIONS

This research effort is somewhat of an outgrowth of an earlier project dealing with driver behavior at signalized intersections which was undertaken by Wortman and Matthias[27,28]. During the course of the field data collection in that project, the use of time-lapse photography proved to be a convenient and efficient means of obtaining a record of numerous driver and traffic variables which were pertinent to the research. In addition, the observation of traffic from the elevated filming location permitted the identification of causes of traffic flow conflicts or problems that were not readily detected when viewed from street level. Furthermore, the viewing of the films during the data reduction phase of the work revealed other conflicts or problems that were not noted at the time of the field studies. The photographic record of the operation of the intersection, therefore, represented a valuable tool for diagnosing intersection problems and evaluating traffic flow.

In the design of the field studies for that project, a certain amount of experimentation with the photographic equipment was necessary before the actual field data collection was initiated. While photographic methods have been used by others in data collection, it was difficult to learn about the proper use of these methods from the information in the literature. This certainly supports the comments by Berger and Sanders[25] in which they indicate the need for gaining experience with such methods. At that time, the wealth of information about the use of photographic and television equipment, which was published a little over ten years ago, had not been found. Generally, the guidance on the use of photographic equipment was limited.

The fact that there was considerable interest in using photographic and television equipment for field studies during the late 1960 and early 1970 period should be noted. In addition, there was even a research effort that was apparently devoted to new methods for studying intersection. Experiments were conducted with equipment which would permit the simultaneous observation of all of the intersection approaches; however there is no evidence that this equipment was further developed. In fact, the equipment which is available on the market today is basically a refinement of the standard equipment that was available at that time.

Based on research undertaken as part of this current project and the experiences gained in using photographic and television equipment, a number of conclusions can be drawn which are pertinent to the study of intersections and even to traffic studies in general. These conclusions can be summarized as follows:

a) For any given problem, it is necessary for highway and traffic engineers to carefully assess the data requirements that are necessary for the solution or evaluation of a problem. There is no single data collection method or technique that is best suited for every situation. A number of factors have been identified which should serve as a guide in selecting data collection methods or techniques.

b) The ultimate use of the field data is an important consideration. If the purpose of the field study is related to diagnosing a traffic problem, then the use of photography or television has major advantages because of the visual record that results. Not only is it possible to simultaneously collect data for a number of variables, the film or video record can later be viewed in the office by a team of individuals who have had experience that is pertinent to the problem. Even when data collection focuses on a specific type of data, the use of photography or television can possibly be a more efficient means of acquiring the information.

c) The location of photographic or television equipment for intersection studies continues to be a major problem, because of the restrictions in the field of view of this equipment, there are limitations in terms of the number of approaches that can be recorded with one camera. If all approaches are to be observed simultaneously, it may be necessary to use more than one camera. In addition, the use of an elevated location for filming is preferable and is sometimes mandatory for a study. Suitable locations are not always available even if a truck with an elevated platform is used.

d) While an extensive list of potential types of intersection studies can be developed, the number of studies that are commonly made by organizations is somewhat limited. For studies associated with signal warrants which must be conducted over a period of several days, the use of traffic volume counters would be a preferable alternative. The use of photographic methods, however, can be considered a reasonable alternative for labor intensive field data collection types of studies such as turn movement volume counts and stop time delay.

e) The types of field study equipment that are currently available on the commercial market generally exceeds that which is available to highway and traffic engineers within an organization. In essence, highway and traffic engineers are not able to take advantage of some types of field study equipment because of the lack of that equipment in their organization.

f) An evaluation of the data reduction time required for the extraction of data from photographic film records indicates time advantages over manual studies which require numerous individuals in the field. Estimates of the time required for data reduction can be predicted on the basis of volume for the turn movement volume study and delayed vehicles for the stop time delay study.

g) In view of the current situation in Arizona, methods which utilize a visual record for data collection offer a feasible alternative to the manual approaches. Such methods can be accomplished with a limited number of personnel. Because of the limitations on the number of personnel who are available for field studies, these methods can be advantageous in terms of the utilization of available staff.

While the project initially set about to recommend procedures for field data collection at intersections, it is difficult if not impossible to recommend a procedure which will be applicable in all situations. The findings of this research do provide additional insights and guidance in terms of the problems associated with intersection field studies. In the process of conducting field investigations with equipment such as the time-lapse camera or video recorders, the research staff began to realize numerous areas where there could be potential applications. In essence, the applications of the equipment was related to experience in using it. The key, however, is to make the equipment available. Even when completely new approaches are devised, acceptance on the part of the user and experience with the application of the approaches are required before they are successfully integrated into practice.

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