

1. Report No. FHWA/TX-82/ +290-1		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Design Considerations For An Urban Freeway Vehicle Detection System				5. Report Date July 1982	
				6. Performing Organization Code	
7. Author(s) William R. McCasland				8. Performing Organization Report No. Research Report 290-1	
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas				10. Work Unit No.	
				11. Contract or Grant No. Study No. 2-18-81-290	
12. Sponsoring Agency Name and Address State Department of Highways and Public Transportation 11th & Brazos Streets Austin, Texas 78701				13. Type of Report and Period Covered Interim - September 1980 July 1982	
				14. Sponsoring Agency Code	
15. Supplementary Notes Research performed in cooperation with DOT and FHWA Research Study Title: Developing a Freeway Data Collection System					
16. Abstract <p>Urban freeways are undergoing significant changes due to reconstruction and rehabilitation of roadways to increase the capacities, to provide for High Occupancy Vehicle (HOV) operations, and to repair damaged and wornout pavements and structures. There is a need for large quantities of timely and comprehensive data on traffic and travel conditions in order to effectively implement these changes. The State Department of Highways and Public Transportation (SDHPT) does not now collect these types of data as part of their state-wide traffic data aquisition program.</p> <p>This project investigates the development of an urban data collection system that employs district personnel to operate automatic traffic recorders on an expanded network of loop detectors embedded in the roadways. The system emphasizes automatic collection and analysis equipment and permanently installed sensors to reduce the manpower requirements.</p>					
17. Key Words Traffic Data Collection, Detectors, Urban Freeway Data Needs.			18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 41	22. Price

DESIGN CONSIDERATIONS FOR AN URBAN FREEWAY
VEHICLE DETECTION SYSTEM

by

William R. McCasland
Research Engineer

Research Report 290-1

Developing a Freeway Data Collection System
Research Study Number 2-18-81-290

Sponsored by

State Department of Highways and Public Transportation
in cooperation with the
U.S. Department of Transportation
Federal Highway Administration

Texas Transportation Institute
The Texas A&M University System
College Station, Texas

July 1982

ABSTRACT

Urban freeways are undergoing significant changes due to reconstruction and rehabilitation of roadways to increase the capacities, to provide for High Occupancy Vehicle (HOV) operations, and to repair damaged and wornout pavements and structures. There is a need for large quantities of timely and comprehensive data on traffic and travel conditions in order to effectively implement these changes. The State Department of Highways and Public Transportation (SDHPT) does not now collect these types of data as part of their state-wide traffic data acquisition program.

This project investigates the development of an urban data collection system that employs district personnel to operate automatic traffic recorders on an expanded network of loop detectors embedded in the roadways. The system emphasizes automatic collection and analysis equipment and permanently installed sensors to reduce the manpower requirements.

DISCLAIMER

The contents of this report reflect the views of the author who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Key Words: Traffic Data Collection, Detectors, Urban Freeway Data Needs

SUMMARY

This report is concerned with the data needs of the SDHPT on urban freeways and the methods for obtaining the data. Urban freeways are undergoing significant changes due to the reconstruction and rehabilitation to increase roadway capacity, to provide for High Occupancy Vehicles (HOV) and to replace worn-out pavements and structures. The demand for large quantities of timely and accurate data is increasing as traffic demand increases. Control plans to handle traffic through the work zones must be developed. Demand estimates for the special HOV roadways must be made to determine the location of access points and the number of lanes required. Operational control plans for HOV facilities that are reversible must be developed. All of the planning and design activities for expanding the freeway network require data that is not readily available through the State's Data Acquisition Program.

This report examines the feasibility of establishing a data collecting system for an urban area that has the capability of collecting data at frequent time intervals at many locations and analyzing the data in a short time period. The data collection system uses automatic data recording and analysis equipment to reduce the manpower requirements.

Two types of sensors are considered - pneumatic tubes placed on top of the pavement and induction loops embedded in the pavement. An analysis of costs, based on the assumption that six hours of data is collected 46 days each year, indicate that the loops embedded in the roadway were the best design because there is less labor involved.

IMPLEMENTATION STATEMENT

A master plan should be developed for each urban area that describes the location of loop detectors on the urban freeway network. All entrances and exits to the freeway and the mainlanes at frequent intervals (approximately 2 miles) should be instrumented with induction loops. The loops can be used as the sensors for the data collection activities and for the surveillance system of freeway management operations. The costs of installation can be reduced if advanced planning is available to include the loops with other construction or maintenance projects (see Appendix A). The costs will be further reduced as the data analysis procedures become more automated through the application of the State's computer systems.

TABLE OF CONTENTS

	<u>Page No.</u>
I. INTRODUCTION	1
Problem Statement.	1
Need For Expanded Detection System	2
Objectives of the Study.	3
II. RESULTS.	5
Data Needs for Urban Areas	5
Volume.	5
Travel Time/Speed	5
Lane Occupancy (Vehicles)	6
Vehicle Classification.	6
Special Surveys	7
Data Detection System Design	7
Proposed Design	8
Loop Configuration.	12
Pull Boxes.	12
III. COST ANALYSIS.	12
Ramp Counts - One Lane	15
Freeway Counts - Four Lanes.	19
Discussion of Costs.	21
IV. CONCLUSIONS.	24
REFERENCES	25
ATTACHMENT A	26
ATTACHMENT B	27

LIST OF FIGURES

<u>Figure</u>		<u>Page No.</u>
1	Low Cost Traffic Control for Loop Installation on Freeway Ramps	10
2	Loop Configuration for Speed Measurement.	13
3	Pull Box Installation	14
4	Pneumatic Tube and Traffic Recorder Installation. . .	16
5	Traffic Recorder Attached to Loop Lead-In	18

LIST OF TABLES

<u>Table</u>	<u>Page No.</u>
1. ATR Stations in the Houston Area	3
2. Summary of Costs for Traffic Counts for Different Methods of Detection	22

INTRODUCTION

PROBLEM STATEMENT

The urban freeways are undergoing significant changes:

- many freeway sections have surpassed the design year loading and require major rehabilitation,
- freeways are being redesigned to accommodate special facilities for High Occupancy Vehicles (HOV) and trucks,
- improvements in design, such as the concrete median barriers, high mast lighting and vehicle crash attenuators, are being implemented, and
- roadway capacities are being increased in bottleneck sections by the use of narrow lanes and shoulders converted to travel lanes,

In addition to these major modifications to the freeway design and operations, the normal maintenance activities must be carefully scheduled because of the high traffic demands that exist during most hours of the day. Any activity that reduces the capacity of the roadway must consider the impact on traffic operations and the need for special traffic controls.

The problem facing the State Department of Highways and Public Transportation (SDHPT) is to obtain the large quantities of timely and comprehensive data that are needed on traffic and travel conditions in order to plan, design, operate and maintain the freeway system of today.

Most districts do not have sufficient staff to conduct the required manual traffic studies. For special studies a traffic consultant is often contracted to conduct the studies. However, there are problems with this approach:

- the time required to develop a contract,
- the ability of the contractor to obtain the type of information

- required, in the time required, and
- the cost effectiveness of some studies.

A district may call on the Transportation Planning Division (D-10) for assistance in collecting the information. If there is sufficient time for planning the studies, D-10 can provide help, but very often they are faced with the same staffing problems as the district.

Very often a district is required to utilize the available data and extrapolate and interpolate to the present time and conditions. This approach is adequate if the traffic records are complete for the areas in question, and if the travel patterns for the freeway have not changed. However, there are many situations for which there is no useful data, and the engineers and planners must rely on judgments based on experience and observations of traffic conditions.

NEED FOR EXPANDED DETECTION SYSTEM

The most basic and pressing need for traffic data is traffic flow rates and volumes. This has been recognized for years with the development of the State's automatic traffic recorder (ATR) stations and the automatic cumulative recorder (ACR) section of D-10.

The ATR normally provides continuous counts on an hourly basis, although the recording intervals can be adjusted to fifteen or five minutes. These data are valuable for developing trends in traffic growth and for extrapolating other data, but the main shortcomings in the urban areas are the limited number and locations of stations. The Houston Area with over 200 miles of freeways has only 17 ATR stations. Table 1.

In the Houston area the ACR uses 24-hour cumulative counters at over 100 locations on the urban freeways. These counts are made every few years

Table 1.

ATR STATIONS IN THE HOUSTON AREA

RECORDER	LOCATION	1980 AVERAGE ADT
A016 IH 45	0.5 MI N OF FM 1960, HOUSTON	66,244
S089 IH 45	1.5 MI SE OF US 59, HOUSTON	147,830
S099 IH 45	0.5 MI SW OF SH 225, HOUSTON	-
S124 US 59	1.1 MI S OF IH 10, HOUSTON	123,722
S139 US 59	4.0 MI E OF IH 610, S. HOUSTON	164,921
S140 US 59	0.6 MI W OF IH 610, S. HOUSTON	195,646
S141 IH 10	0.8 MI W OF IH 610, W. HOUSTON	139,321
S142 IH 45	0.4 MI S OF IH 610, N. HOUSTON	124,542
S154 IH 10	0.8 MI E OF US 59, E. HOUSTON	-
S155 IH 10	0.8 MI W OF IH 610, E. HOUSTON	92,699
S156 IH 610	1.4 MI S OF IH 10, W. HOUSTON	190,744
S157 IH 610	0.7 MI W OF IH 45, N. HOUSTON	143,251
S165 IH 10	0.5 MI W OF IH 45, HOUSTON	106,057
S166 IH 610	0.3 MI W OF US 90A, S. HOUSTON	119,441
S172 IH 610	1.0 MI W OF IH 45, S. HOUSTON	106,899
S176 IH 10	0.5 MI W OF US 59, HOUSTON	81,432
S182 IH 610	N. END HOUSTON SHIP CHANNEL BRIDGE	97,652

and are used to expand the ATR data. However, in a developing urbanized area, traffic patterns can change dramatically in a short time. Also, without the short time interval counts the data cannot be used in many design, maintenance, and operational decisions.

In a report on traffic data requirements in Texas, conducted in 1979-80 it was concluded that "the urbanized districts indicated that traffic volume information currently available is generally inadequate for their needs and require more data produced on a more frequent basis¹."

OBJECTIVES OF THE STUDY

In September 1980 HPR Study 290 entitled "Developing a Freeway Data Collection System" was initiated with the objectives to define the data needs and to develop a data collection procedure that satisfies those data needs for the urban freeways in Texas. The study would also assist the SDHPT in establishing a pilot study to implement the data collection system and to develop an urban traffic data management system for the storage, analysis and retrieval of the data.

RESULTS

DATA NEEDS FOR URBAN AREAS

A state-wide survey of the needs of traffic information was conducted for the SDHPT in 1978. The results of this survey was used in this study to refine the data needs through the use of interviews with district personnel in Houston and experienced personnel of SDHPT Headquarters Offices in Austin. Specific uses of data were identified and applied both to a designated freeway and to the overall freeway system in Houston. The following is a review of the needs as obtained from these discussions.

Volume

Permanent ATR and the ACR provide 24-hour counts for many sections of the freeway once a year. The ATR data can be used to estimate counts at other times of the year at other freeway locations. However, daily variations of flow on the ramps, frontage roads, and mainlanes can not be precisely determined.

Therefore, an expanded freeway counting system, to include the ramps and frontage roads, that will provide access to traffic flow data at 5 and 15 minute intervals at any time of the year is required.

Travel Time/Speed

District personnel conduct travel time/speed surveys once every two or three years using tachograph units mounted in state vehicles. A more frequent schedule of data collection is desired, but not critical. A traffic detection system or other automatic system which determines "spot

speeds" (speed of traffic at the detector location) on a regular basis would supplement and expand the periodic travel time/speed surveys. The use of spot speeds could also reduce the number of travel time/speed surveys.

Therefore, an expanded count system that can provide speed data at frequent locations is desired.

Lane Occupancy (Vehicles)

The measure of time that vehicles occupy an area over the roadway is important in the evaluation of the quality of traffic operations, since it combines the factors of speed and volume. This measure is used in freeway traffic control systems, and can also be applied to freeway simulation models and other analytical methods for evaluating traffic operations.

Therefore, the data system should be capable of measuring lane occupancy.

Vehicle Classification

D-10's current programs of vehicle classification and truck weight surveys are designed to satisfy Federal requirements. The use of this truck data in urban areas has been minimal, even though it is useful in pavement design. However, the concerns of truck traffic in urban areas and their effects on pavement deterioration, traffic operations, and safety have increased.

There is concern for the life of pavement shoulders that have been converted for travel, if a large number of heavy loads are applied. Roadway sections that have been realigned with narrow lanes may have safety problems

when large volumes of large vehicles are present in the traffic. The presence of large volumes of large vehicles with heavy loads may reduce the efficiency of the roadway and safety of operation if low speeds result. Some agencies are considering the implementation of lane restrictions or travel prohibitions for trucks during certain hours.

Therefore, the data system should have detection stations that can provide information on the volume of truck traffic.

Special Surveys

There are many other traffic data that are useful and necessary in the development in the design and operation of the freeway. These include measures of:

- Noise Level
- Air Quality
- Fuel Consumption
- Origin-Destination Patterns
- Vehicle Occupancy (Passengers per vehicle)

The information that would be collected by the data system - volume, speed, vehicle classification - is needed in the conduct of these studies, but the direct measures of the quantities for the special studies requires manual procedures and will not be included in this data collection system.

Therefore, the data system should support these special studies, but additional field equipment would not be provided.

DATA DETECTION SYSTEM DESIGN

The data needs identified from the urban districts were analyzed with

respect to the available means for collecting traffic data; that is, manual vs. automation, district staff vs. Austin staff, and district staff vs. consultant. Critical design requirements for the data system are:

- many data locations,
- limited amounts of data collected at frequent intervals,
- minimum field personnel requirements for collection of data, and
- minimum office personnel requirements for data analysis.

Proposed Design

The proposed design to satisfy these requirements is:

1. Install loop detectors on each entrance, exit and freeway connecting roadway in the urban freeway network.
2. Install loop detectors on the main lanes of the freeways, frontage roads, and interchange cross streets at frequent intervals, This interval will vary with the frequency of ramps, volume of traffic, location of bottleneck sections and other factors. An average spacing of 2 miles is recommended for the freeway mainlane detection station.
3. Obtain traffic recorder systems that are portable, adaptable to loop detectors and provide simple analysis routines without manual manipulation of data. One example is the Marksman traffic survey equipment supplied by the Golden River Company.
4. Operate the data systems with district personnel.

The installment of loops in the pavement of the freeway system is essential to the development of the data collection system. Without these sensors permanently installed in the roadways, the following procedures would be necessary:

- On single lane roadways such as ramps, connecting roadways and low volume two and three lane roadways, such as frontage roads, pneumatic road tubes or loop detectors taped to the surface of the pavement would be used. The count accuracy is acceptable, but the increase in costs and manpower to accomplish the installation is undesirable.
- For freeway mainlane counts, the recorder system would be connected to the nearest ATR. All ramps between the ATR and the desired freeway location would be counted either manually or with surface mounted sensors. This approach would require large number of ramp counts, since the ATR's may be 4 or 5 miles away from the desired count location.

It is recommended that the loop detectors sensors be embedded in the roadway and the loop leads terminated in a pull box adjacent to the roadway. Figure 1. These installations can be made at low costs on the ramps, since the traffic handling requirements are very low. Consideration should also be given to installing conduit and detector lead-in wire from the pull box to a cabinet at the nearest cross street interchange.

On the mainlanes the installations should be made in conjunction with other maintenance and construction operations as suggested in the Administrative Circular N. 38-80, dated July 22, 1980 (Attachment A). Estimates show that approximately half the costs of a loop installation on the mainlane of a freeway are for traffic handling. The installation of loops in the pavement are relatively inexpensive. The latest cost for the placement of a 6-ft by 6-ft loop with a 20 foot lead-in was \$ 700.

The location of detectors is usually site specific, but the following



Figure 1
Low Cost Traffic Control For Loop Installation on Freeway Ramps

guidelines are applicable in most instances:

- Entrance Ramps - The detectors may become part of a ramp metering system. The loop should be located downstream of the proposed location of the meter signal.
- Exit Ramps - The loop should be located far enough away from the freeway to be positioned between the normal wheel tracks of vehicles exiting the freeway.
- Freeway to Freeway Connectors - The detectors may be part of a traffic control system. The loop should be located downstream of the proposed control point. The loop should not be located on a bridge structure.
- Freeway Mainlanes - The detection station may be used in a freeway control system. If possible, the detectors should provide traffic operational data of freeway bottleneck sections. It is preferable to locate the station adjacent to an exit ramp so that the mainlanes and the exit ramp can be detected with one traffic recorder.
- Frontage Roads - The detection station may be used for traffic signal control, and should be located 500 to 1000 feet in advance of the intersection with the cross street.

For all detectors, the exact location can be adjusted to improve the installation by reducing the amount of pavement cuts, avoiding pavement cracks and joints, and providing good locations for the pull box where the traffic recorder will be connected.

The freeway detectors may become an ATR in the future, and considerations of recorder locations, electrical connections, and accessibility for maintenance should be included in the designs.

Loop Configuration

A 6-ft by 6-ft loop is positioned in the center of the lane to be detected. There has been some work with diamond configurations (see Attachment B), but there have been some problems with quality control of that type of design. Regardless of the design, careful inspection of the installation of the wire is essential.

On the mainlanes, the second lane from the right has two loops separated by 12 feet from the trailing edge of the first to the leading edge of the second (Figure 2) for speed measurements.

At selected locations, the second loop can be used for vehicle classification measurements. If a total vehicle classification measurement is required, each lane would be equipped with 2 loops.

Pull Boxes

The loop leads are run to the outside of the roadway and connected to a terminal strip in a pull box. The box should be designed to drain freely to avoid standing water, and should be located out of the path of traffic. Figure 3.

COST ANALYSIS

To illustrate the cost effectiveness of placing loop detectors in the pavement for the collection of traffic data, the following analysis is presented for three methods of data collection - manual counting, pneumatic tubes and an automatic traffic recorder, and loop detectors embedded in pavement and an automatic traffic recorder. Two locations,



Figure 2
Loop Configuration for Speed Measurement



Figure 3
Pull Box Installation

freeway ramps and freeway mainlanes, are considered.

The analysis is based on the requirement to collect data for two 3-hour peak periods at 15 minute intervals for a 3 day period and a 7 day period at a location that is 5 miles from the office*. The hourly rate for all personnel is \$10/hour.

Ramp Counts - One Lane

1. Manual Counts - A ramp count can be made with one person. The data analysis is assumed to require one hour for each three hours of field data.

- For the 3 day study, the costs are:

Data Collection: 1 man @ \$10/hour for 18 hours	= \$ 180.00
Travel Costs: 60 miles @ 23¢/miles	= 13.80
Travel Time: 1 man @ \$10/hour for 3 hours	= 30.00
Data Analysis: 1 man @ \$10/hour for 6 hours	= <u>60.00</u>
Total Cost for 18 hours of data	= \$ 283.80

- For the 7 day study, the costs are directly proportional to the length of the study.

Total Cost for 42 hours of data	= \$ 662.20
---------------------------------	-------------

2. Pneumatic Tube Counts - A pneumatic tube can be installed and retrieved by two men in one hour. Figure 4. The data analysis is assumed to require one hour for each study, regardless of the length of the study. A road tube on the surface of the pavement is subjected to stress and failures due to the impacts of the vehicles. A 10 percent failure rate is applied to cost of installation.

* The costs would be essentially the same for shorter time intervals such as 5 or 10 minutes.



Figure 4

Pneumatic Tube and Traffic Recorder Installation

- For the 3-day study, the costs are:

Data Collection: 2 men @ \$10/hour for 1 hour x 1.10	= \$ 22.00
Travel Costs: 20 miles @ 23¢/mile x 1.10	= 5.06
Travel Time: 2 men @ \$10/hour for 1 hour x 1.10	= 22.00
Data Analysis: 1 man @ \$10/hour for 1 hour	= <u>10.00</u>
Subtotal Cost for 18 hours of data	= \$ 59.06

To collect and analyze the data, electronic equipment costing \$2,400 will be used. If we assume a useful life of 5 years, and a usage rate of 150 days per year, the daily use charge would be \$4.22 per day*.

Data Equipment for the 3-day study	= \$ <u>12.66</u>
Total Cost for 18 hours of data	= \$ 71.72

- For the 7-day study, the costs are the same, except for the usage charge of the equipment.

Total Cost for 42 hours of data	= \$ 88.60
---------------------------------	------------

3. Loop Detector Counts - A traffic recorder can be installed, attached to a loop detector that is embedded in the pavement, and retrieved by one man in 0.5 hours. Figure 5. The data analysis is assumed to require 1 hour for each study, regardless of the length of the study.

- For the 3-day study, the costs are:

Data Collection: 1 man @ \$10/hour for 0.5 hour	= \$ 5.00
Travel Costs: 20 miles @ 23¢/mile	= 4.60
Travel Time: 1 man @ \$10/hour for 1 hour	= 10.00
Data Analysis: 1 man @ \$10/hour for 1 hour	= <u>10.00</u>
Subtotal Cost for 18 hours of data	= \$ 29.60

* Capital Recovery Factor of 0.2638 for 5 years at an interest rate of 10% is used to determine cost.

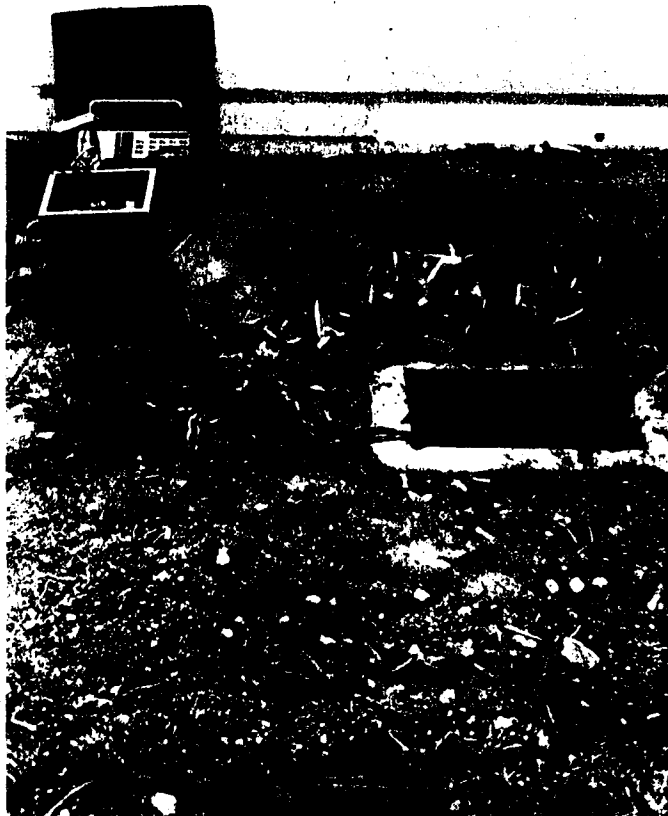


Figure 5

Traffic Recorder Attached to Loop Lead-Ins

The data recorder and analyzer is the same as that used with the pneumatic tube. The cost per day is \$4.22. The cost to install the loop detector in the pavement of the ramp is estimated to be \$750*. If the loop has a useful life of 10 years, and if a count will be made from the loop 46 days per year, the daily usage cost would be \$2.66 per count per day**.

For the 3-day study, the equipment cost would be = \$ 20.64

Total Cost for 18 hours of data = \$ 50.24

● For the 7-day study, the costs are the same except for the user charge of the equipment.

Total Cost for 42 hours of data = \$ 77.76

Freeway Counts - Four Lanes

1. Manual Counts - Freeway counts require two persons. The data analysis is assumed to require one hour for each three hours of field data.

● For the 3-day study, the costs are:

Data Collection: 2 men @ \$10/hour for 18 hours = \$ 360.00

Travel Costs: 60 miles @ 23¢/mile = 12.60

Travel Time: 2 men @ \$10/hour for 3 hours = 60.00

Data Analysis: 1 man @ \$10/hour for 6 hours = 60.00

Total Cost for 18 hours of data = \$ 492.60

● For the 7 day study, the costs are directly proportional to the length of the study.

Total Cost for 42 hours of data = \$1149.40

* The cost of the loop installation with pullbox could be \$600 if the loop is installed as part of a construction or reconstruction project during which time the ramp is closed.

** Capital Recovery Factor of 0.16275 for 10 years at an interest rate of 10% is used to determine annual cost.

2. Pneumatic Tube Counts - Two pneumatic tubes, each covering two lanes, can be installed and retrieved by 5 men in two hours. The additional time and manpower is required to control traffic during the installation. The higher payrate represents time-and-a-half for work on weekends when traffic is light. The data will be collected on two recorders, but the time of analysis will still require only one hour. A 10 percent failure rate for the operation of the roadtubes is applied.

- For the 3-day study, the costs are:

Data Collection: 5 men @ \$15/hour for 2 hours x 1.10	= \$ 165.00
Travel Costs: 20 miles @ 23¢/mile x 1.10	= 5.06
Travel Time: 5 men @ \$15/hour for 1 hour x 1.10	= 82.50
Data Analysis: 1 man @ \$10/hour for 1 hour	= 10.00
Data Equipment: 2 recorders @ \$4.22/day for 3 days	= <u>25.32</u>
Total Cost for 18 hours of data	= \$ 287.88

- For the 7-day study:

Total Cost for 42 hours of data	= \$ 321.64
---------------------------------	-------------

3. Loop Detector Counts - A traffic recorder can be installed, attached to 4 loop detectors embedded in the pavement and retrieved by one man in 1 hour. The data analysis will require one hour for the study.

- For the 3-day study, the costs are:

Data Collection: 1 man @ \$10/hour for 1 hour	= \$ 10.00
Travel Costs: 20 miles @ 23¢/mile	= 4.60
Travel Time: 1 man @ \$10/hour for 1 hour	= 10.00
Data Analysis: 1 man @ \$10/hour for 1 hour	= 10.00
Data Equipment: 1 recorder @ \$4.22/day for 3 days	= <u>12.66</u>
Subtotal Cost for 18 hours of data	= \$ 47.26

The cost to install the four loop detectors in the pavement of the freeway is estimated to be \$5,000*. For a useful life of 10 years and a frequency of usage of 46 days per year, the daily usage cost would be \$17.69 per count per day**.

For the 3-day study, the detection cost would be: = \$ 53.07

Total Cost for 18 hours of data = \$ 99.93

● For the 7-day study:

Total Cost for 42 hours of data = \$ 187.57

The annual costs of the three systems is based on a usage rate of 46 days per year. It is estimated that a full 7-day count will be made once each quarter of the year to establish traffic trends and seasonal adjustments. Six three-day counts are estimated for use in conjunction with maintenance and rehabilitation projects, traffic control plans and other operational requirements. A three-day count is used to provide 3 one-day counts to reduce the impact of daily fluctuations in the traffic patterns. For the automatic counts, the differential costs of 1 and 3 day counts are very small.

Table 2 summarizes the costs for 1, 3, 7, and 46 days.

Discussion of Costs

The cost analysis assumes that only six hours of data is collected 46 days each year. The two automatic methods of detection can provide

* The cost of the loop installation with pull boxes could be \$2,000 if the loops are installed while the mainlanes are closed during a construction or reconstruction project.

** Capital Recovery Factor of 0.16275 for 10 years at an interest rate of 10% is used to determine annual cost.

Table 2.

SUMMARY OF COSTS FOR TRAFFIC COUNTS
FOR DIFFERENT METHODS OF DETECTION

A. RAMP COUNTS - COST OF STUDY

METHOD OF DETECTION \ LENGTH OF STUDY	1 DAY	3 DAYS	7 DAYS	46 DAYS*
Manual	\$ 94.60	\$ 283.80	\$ 662.20	\$ 4351.60
Pneumatic	63.28	71.72	88.60	784.72
Loops	36.48	50.24	77.76	612.48

B. FREEWAY COUNTS - COST OF STUDY

METHOD OF DETECTION \ LENGTH OF STUDY	1 DAY	3 DAYS	7 DAYS	46 DAYS*
Manual	\$ 164.20	\$ 492.60	\$ 1149.40	\$ 7553.20
Pneumatic	271.00	287.88	321.64	3013.84
Loops	56.11	99.93	187.57	1349.86

* The 46 days represent the annual counting schedule of four 7-day counts and six 3-day counts.

24-hour per day coverage with no additional cost. So, it is obvious that manual costs are very expensive, but they have some advantages such as, the flexibility of time and location of study and the ability to collect vehicle classification and vehicle occupancy without additional cost. Manual counting procedures also provide the capability of qualitative information on traffic operations. However, for the basic requirement of collecting traffic flow rates and volumes, an automatic collection and analysis system is the most cost effective.

The decision to use temporary traffic sensors on top of the roadway or permanently installed loops embedded in the roadway can be justified on costs if the assumed usage rate of 48 days per year is valid. But there are also many other advantages in having loop detectors in the pavement:

- Counts based on presence detection are more accurate than counts of axles.
- A 'one time' installation of loops reduces the hazard to workers.
- A 'one time' installation of loops reduces the adverse impact on the traffic flow.
- Loop detection would reduce the amount of bad data resulting from equipment malfunctions, such as roadtube breakage.
- Loop detection can be incorporated into an electronic surveillance and control system.
- A detection station can be activated by one person in a short time with little advanced notice.
- Loop detection provides greater flexibility in the collection of data other than vehicle counts. Vehicle occupancy and speed estimation can be obtained from one loop; speed estimation and vehicle classification from two loops.

CONCLUSIONS

The need for large quantities of data collected at many locations at frequent time intervals is increasing. The principal need is for traffic volumes and flow rates, but information on speed and vehicle classification is also useful.

The use of equipment and procedures that minimize manpower requirements is the preferred approach. Sensors embedded in the roadway, attached to recorders that can automatically record and analyze the data and transmit the data to a computer, is the most cost effective design.

REFERENCES

1. "Texas Traffic Data Acquisition Program", Han-Jei, Clyde E. Lee, R.B. Machemehl. Center for Highway Research Report No. 245-1F, February 1980.

ATTACHMENT A

ADMINISTRATION CIRCULAR NO. 38-80

To: All District Engineers and Engineer-Manager

Date: July 22, 1980

Subject: Vehicle Detector Loops
on Urban Freeways

Expires: Upon Receipt

Reference:

File: D-10

Gentlemen:

Urban Freeway traffic data continues to become more difficult to obtain, while the need for such continues to increase.

In an attempt to ultimately obtain needed data, reduce the hazards involved with equipment installation and minimize inconvenience to the traveling public, the following procedures are to be implemented immediately. Whenever projects are proposed which involve urban freeway surface modification (Seal Coat, Overlay, Extensive patching, etc.) and which involve temporary lane blockage, File D-10 should be advised at an early date. This will allow time for arrangements for loop detector placement as determined to be necessary by that office. Also, detectors for possible freeway operational needs as determined by the District and/or others should be installed at this time when different from, or in addition to, locations selected by File D-10.

Similar consideration should also be given to any proposed new urban freeway construction projects.

Sincerely yours,

(Original signed by M. G. Goode)

M. G. Goode
Engineer-Director

DISTRIBUTION:

District Engineers
Engineer-Manager

ATTACHMENT B

THE ADJUSTABLE LOOP FOR VEHICLE DETECTION

*Wendell A. Blikken, Associate Member,
I.T.E.

INTRODUCTION

The loop development to be described lies in a current Michigan Dept. of Transportation project begun 1 January 1979. This Surveillance, Control, and Driver Information project, abbreviated as SCANDI, is for the free-ways of Detroit. Traffic flow parameters to be measured include vehicle count, average speed, and occupancy. A diamond loop and adjustment technique, matched to a digital detector, has shown improved count and vehicle detection accuracy.

A basic decision to place these vehicle sensing loops, with appropriate detectors, every 1/2 km. (1/3 mi.) in each freeway lane was made early in the system design phase. Count accuracy requirements dictated an immediate test and development program to assure wholesale production capability for loops having the proper characteristics of coverage and sensitivity. Available published data was inadequate.

REQUIREMENTS

Testing of the common standard 3 turn 6 ft. x 6 ft. square loop began using available detectors. Specifications were developed during the process of testing assumptions, and are itemized in Figure 1 as:

1. All vehicles are to be detected as a single entity, including high bed trucks of semi-trailer, trailer, and tanker configuration.
2. Vehicles partially in a lane are to be detected only if greater than 50% of the vehicle, longitudinally, is in the lane.
3. The vehicle track, i.e., succession of positions on the roadway, during detection shall be independent of vehicle speed.
4. Detectors are to be reliable, interchangeable, and accurately resettable. Simplicity of setting of controls is to be strongly favored for human engineering purposes.

*Engineer, Michigan Dept. of Transportation

5. All loops are to have the same width of sensing zone, i.e., cover only a lane for a given detector sensitivity. The loops must also be as mechanically identical as possible for simplicity of the specification and fabrication processes.

INITIAL FIELD TESTS

Initial tests of the common 3 turn 6 ft. x 6 ft. square loop were primarily for detector evaluation as the loop design problem was unknown at the time and revealed a variety of detector shortcomings. The timely arrival of a 4-channel digital detector, which met all the requirements of #3 and #4 above, permitted detector testing to be terminated. However, the feature of adjusting the sensitivity of the digital detector by extending the time duration of loop excitation, was a significant limitation. Due to the time-sharing of 4 loops, it was found that sensitivity 2, next to the lowest, was the maximum acceptable sensitivity consistent with system data-sampling minimums. This aggravated the loop performance requirements and forced additional loop development to complement the low sensitivity adjustment of the chosen detector. It was recognized that the loop was the only component capable of an adjustment to control the aspect ratio (height to width) of the vehicle sensing zone of the loop-detector subsystem.

Consistent with requirement 5, above, selection was made to develop the standard square loop, ROTATED INTO THE DIAMOND POSITION, and exploit only ANGULAR changes to adjust the width of the sensing zone, once the subsystem detection sensitivity requirement was met. The four sides of the diamond loop constitute the minimum number for a geometric figure with angular flexibility and retain the same number of passes of the concrete-cutting saw as the square loops which avoids increasing a labor-intensive process. Thus, use of the same number and length of loop sides of the common 6 ft x 6 ft. loop simplified procurement as it left only the number of turns of wire as the changed component of the diamond loop for the cost estimation and bidding processes.

Patent Pending

INTERMEDIATE FIELD TESTS

Performance deficiencies of the 3 turn square loop are shown in Figures 2, 3 and 4 for some vehicles on the I-75 freeway in Detroit. As shown, it appeared that sensitivity had to be increased by 2^2 (each step gives a doubling of sensitivity) in order to detect semi-trailer rigs. Increasing the loop to 7 turns was found to meet this performance requirement for vehicles traveling in the center of the lane.

Subsequent performance measurements on a standard 4 door vehicle, selected as the typical vehicle, were then made for determining transverse coverage of the 7 turn loop and digital detector at sensitivity 2, as a proposed standard. The diamond loop was tested for width of vehicle sensing on an unopened section of multi-lane freeways providing an excellent test site. Repeated vehicle passes were made parallel to lane center and at increasing displacements from lane center in order to determine detection limits. It was then a simple procedure to reduce the width of the diamond by the excess width of detection zone coverage (in the adjacent lane). Performance of this combination was also tested on the I-75 freeway in Detroit with the results shown in Figures 5, 6, and 7.

The tanker picture, Figure 8, shows the clear space under the round tank center which makes it the most difficult vehicle to detect for continuity from end to end. It is estimated from the inverse square law that the high center portion gives about 1/50 the effect on the loop of the selected typical vehicle.

CALIBRATION PROCEDURE

From this experience a method for calibration of the diamond was developed and consists of taping a portable loop to a typical roadway and using an arbitrary initial selection of corner angles, e.g., 90° , for the first trial position. After energizing the loop with a detector, the selected typical vehicle may then be driven over the loop parallel to lane center at various displacements from center until the edge of the sensing zone, and ΔW from vehicle center, is determined. The loop may then be narrowed by $2W$ and the adjustment verified using runs repeated with vehicle center in the vicinity of lane edge as shown in Figure 9.

When the loop width adjustment is complete, a probe coil, Figure 10 may be placed at lane edge opposite the near diamond corner and an associated tuneable voltmeter used to measure the established field strength for future reference at other loop sites. At subsequent locations, the portable loop need only be adjusted in width to obtain this established reference value; occasional verification has been used to build confidence. This completed the calibration process.

Convenient improvements for field use include a non-scanning detector (a factory modification) for stableness of the voltmeter reading, and a mount for the portable loop consisting of a non-conducting, non-magnetic frame (1"x3" wood strips and dowels can give a respectable service life). When using the mobility of a van with an a.c. generator aboard, experienced 3 person crews have marked 150 loop sites in less than 24 hours during a freeway closure in the summer of 1978. Figures 11, 12, 13, and 14 show the major components of van, voltmeter and energizing detector, loop and probe coil in place for loop adjustment, and the crew marking the pavement from the adjusted loop for the cutting saw.

FINAL FIELD TEST RESULTS

Field tests of vehicle count for 1/2 km. sections of highway between two lines of loops (one per lane) were made on two different sections of freeway. One section had been equipped with loops during an earlier opportune highway closing and employed the old standard 3 turn 6 ft. x 6 ft. square loops. The other section employed the adjusted diamond loops. Simultaneous video tape recordings were made of the traffic for reference count purposes. These data of Figure 15 compare as follows:

	<u>3T6x6 Sq. Loop</u>	<u>7T6x6 Diamond Loop</u>
Traffic Condition	Minimum weaving, no ramp in section	Maximum weaving for major intersection immediately downstream, no ramp section
Traffic Mix	.03% trucks	12.5% trucks
Manual count of vehicles	3114	4670
Electrical Count by loop-detector	3160	4684
Difference from manual count of video tape of same vehicles, slowdown playback	1.48%	0.30%
Loop width variation	0 for 1:1 ratio	1.6:1 ratio

CORRELATION TEST

A graphical analysis of loop width vs. inductance was made to check for correlation of one with the other. Figures 16, 17, and 18 shows the result in which no eyeball correlation is discernable. Indeed, the greatest inductance of $500 \mu h$ occurred for a relatively narrow loop. This result strengthens our

belief that these variations are caused by some other parameter, e.g., the spacing between loop and reinforcement rod in the concrete as has been suggested by Mr. P. K. Mills of the FHWA, Washington, D.C. in private communications. Whatever the cause, we have been gratified by the test results above.

The author received capable assistance and support from many persons, notably James Belles

for design and fabrication of field equipment, George Wood for field testing, Gordon Paesani and Arvyd Satraitis for data analysis with critiquing, all of Michigan Department of Transportation, Ralph and Steve Koerner of Canoga for detectors and advice, and Mr. H. L. Crane of Michigan Dept. of Transportation for administrative support, beginning when faith was paramount.

FIG. 1 LOOP DETECTOR SPECIFICATIONS

- 1) All vehicles are to be detected as a single entity, including high bed trucks of semi-trailer, trailer, and tanker configuration.
- 2) Vehicles partially in a lane are to be detected only if greater than 50% longitudinally are in the lane.
- 3) The vehicle track in the roadway during detection shall be independent of vehicle speed.
- 4) Detectors are to be reliable, interchangeable, and accurately resettable. Simplicity of setting of controls is to be strongly favored for human engineering purposes.
- 5) All loops are to have the same width of sensing zone for a given detector sensitivity. The loops must also be as identical as possible for specification and fabrication purposes.

FIG. 2 RESPONSE OF 7 TURN 6x6 FT. \diamond LOOP @ 2 DETECTOR SENSITIVITIES

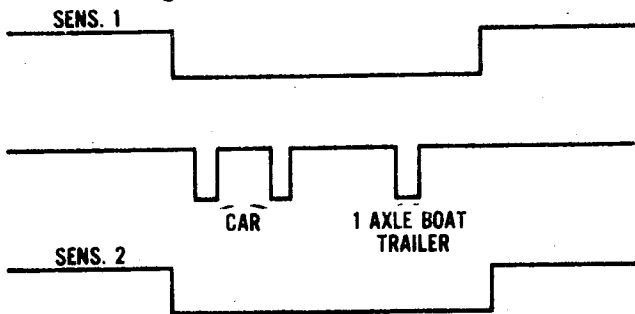


FIG. 3 RESPONSE OF 3 TURN 6x6 FT. LOOP @ 2 DETECTOR SENSITIVITIES

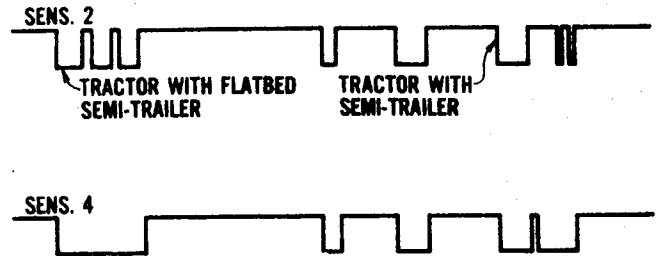


FIG. 4 RESPONSE OF 3 TURN 6x6 FT. LOOP @ 2 DETECTOR SENSITIVITIES

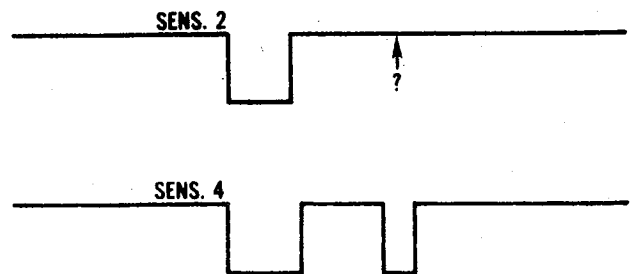


FIG. 5 RESPONSE OF 7 TURN 6x6 FT. LOOP
@ 2 DETECTOR SENSITIVITIES

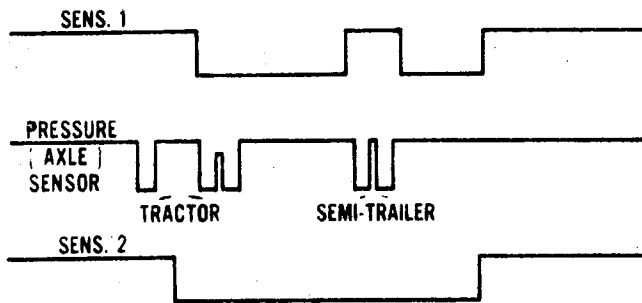


FIG. 6 RESPONSE OF 7 TURN 6x6 FT. LOOP
(a) 2 DETECTOR SENSITIVITIES

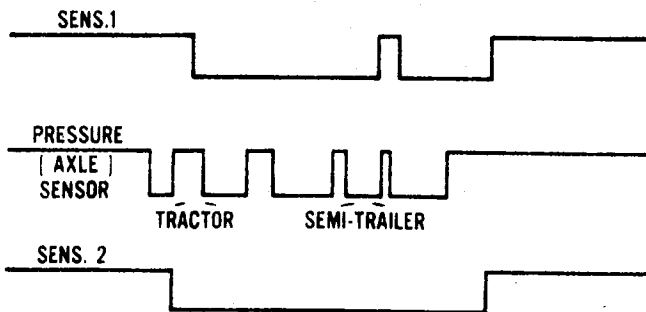


FIG. 7 RESPONSE OF 7 TURN 6x6 FT. LOOP
@ 2 DETECTOR SENSITIVITIES & WHEELS IN LANE CENTER

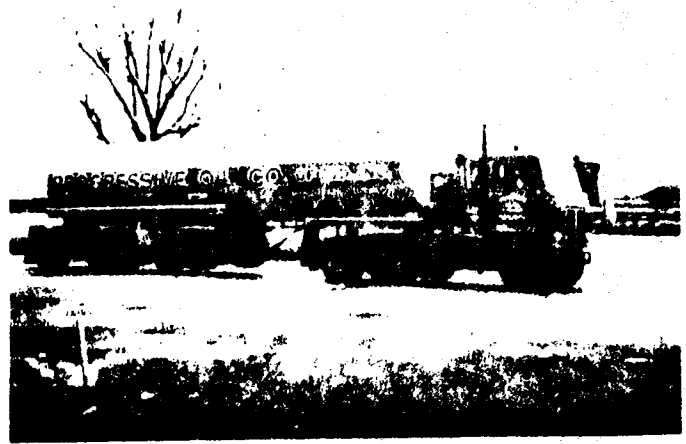
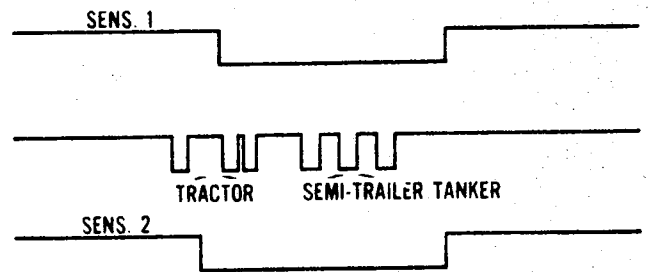
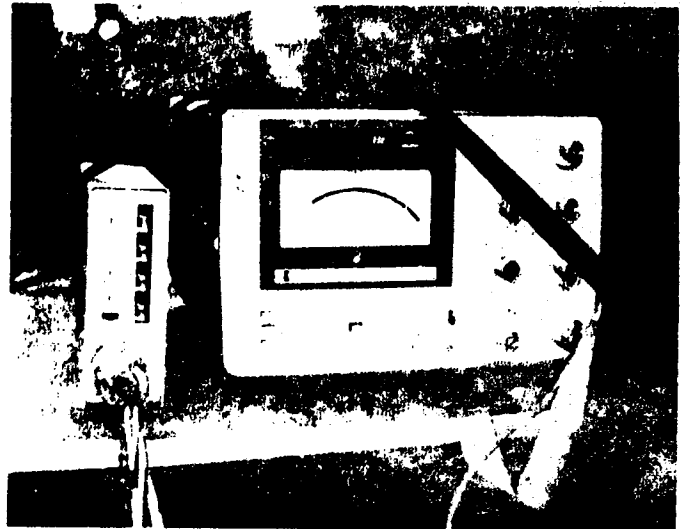
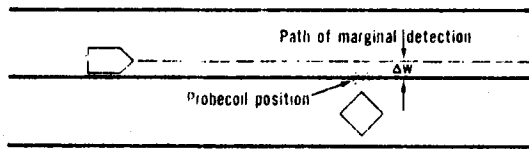


FIG. 9 CALIBRATION LAYOUT



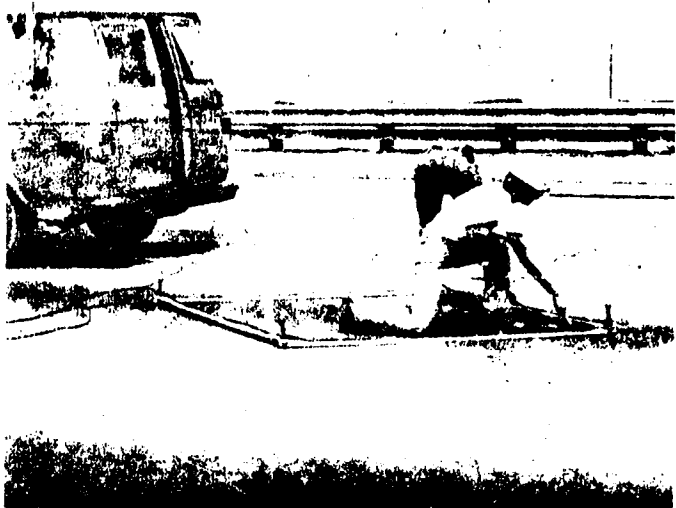
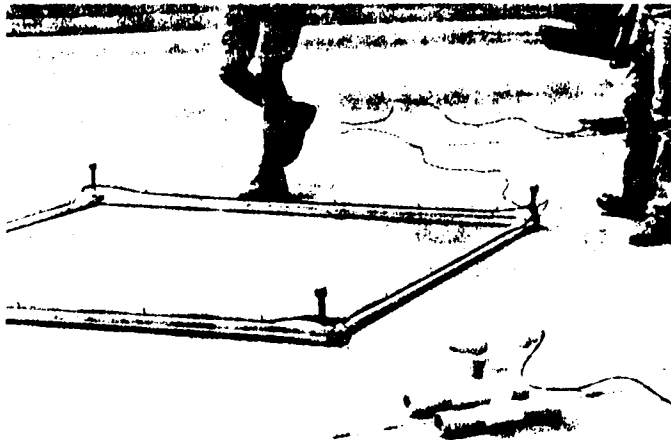


FIG. 15 LOOP PERFORMANCE COMPARISON

	116x6 Sq. Loop	716x6 Diamond Loop
Traffic Site Condition	Minimum weaving no ramps in section	Maximum weaving for major intersection immediately downstream, no ramps in section
Traffic Mix	0.3% Trucks	12.5% Trucks
Manual count of vehicles	3114	4670
Electrical Count by loop detector	3160	4684
Difference from manual count of video tape of same vehicles slowdown playback	1.48%	0.30%
Loop width variation	0 for 1:1 ratio	1.6:1 ratio

FIG. 16 WESTBOUND EISEL FORD FREEWAY

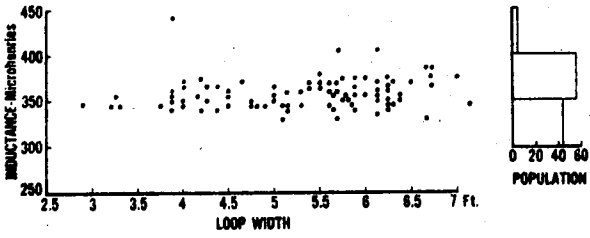


FIG. 17 EASTBOUND EISEL FORD FREEWAY

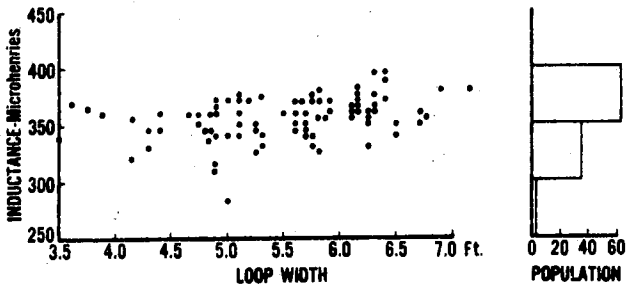


FIG. 18 SOUTHBOUND CHRYSLER (I-75) FREEWAY

