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REMOVAL OF MULTIWAY STOP SIGNS WITH MINIMUM HAZARD

VOL. I TECHNICAL REPORT

U.S. Department
of Transportation

**Federal Highway
Administration**

Research, Development,
and Technology

Turner-Fairbank Highway
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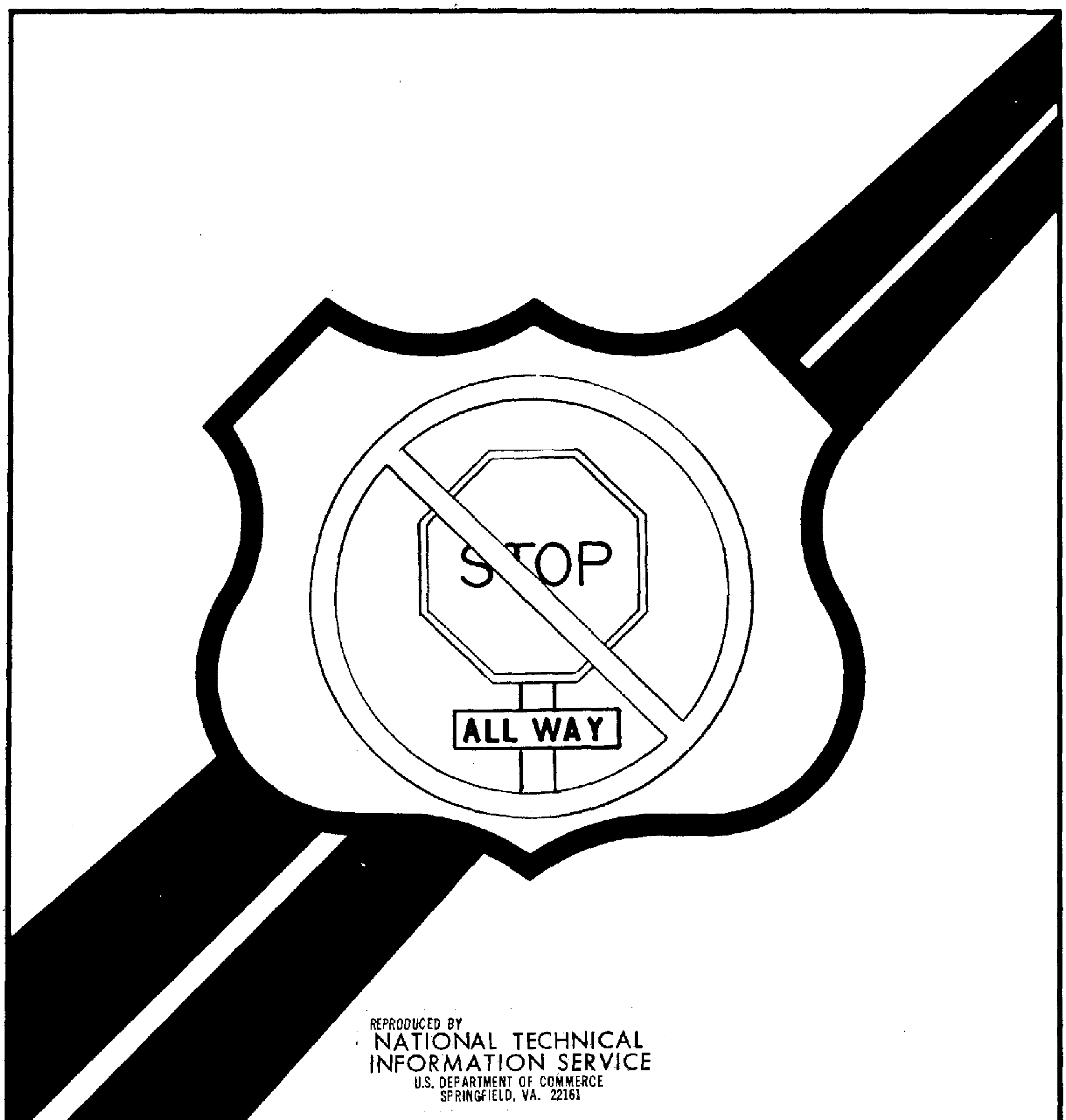

FOREWORD

This report will be of interest to traffic engineers and city officials who are interested in converting unwarranted four-way stop sign intersections back to two-way control. After reviewing the procedures for removing four-way stops in a number of localities throughout the country, a procedure was developed and tested to make these conversions, and the results are presented in this report.

The need for this research was identified from problem statements received from Austin, Texas; Houston, Texas; Bloomfield Hills, Michigan; and from FHWA's Office of Highway Safety. This study was part of the Federally Coordinated Program (FCP) for Research and Development, Project 1A, "Safety and Traffic Control Devices."

The report is being distributed to provide a minimum of one copy to each regional office, division office and State highway agency. Direct distribution is being made to division offices. In addition, copies are being sent directly to local traffic engineers around the country.

Stanley R. Byington, Director
Office of Safety and Traffic Operations
Research and Development

NOTICE

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16. Abstract

This study reports on the experience of more than 30 political jurisdictions throughout the United States which have converted multiway, stop sign-controlled intersections to lesser forms of controls. In all instances, those officials interviewed during field visits reported converting 4-way or 3-way stop intersections to 2-way or 1-way stop intersections. A great variety of procedures and accompanying notice, caution, and warning signs were found to have been used in the conversion of the more than 172 intersections studied. Generally, low volume, low speed, residential intersections were being converted safely without the use of supplementary signs. As intersection volumes increased, there was an increased need for multiway stop sign-intersection conversion aids. Procedures were developed by which multiway stop sign-controlled intersections can be converted to lesser forms of control with minimum hazard. Signs installed prior to the conversion provided motorists with the date of the conversion. Signs placed under the remaining stop signs after conversion should read "CAUTION, CROSS TRAFFIC DOES NOT STOP." Any stop line pavement markings on the new through street should be removed.

Volume I reports on the overall study effort. Volume II addresses details of the recommended conversion procedures for use as a guide by local officials.

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The research team wishes to acknowledge the assistance of the many local municipal managers, traffic engineers, police officials, and others who graciously consented to participate in the study. They are listed in Appendix A. It is their collective experiences that we have documented and analyzed. Particular thanks to the town of Manchester, Connecticut and Officer Gary J. Wood, and Kansas City, Missouri and Dr. Russi Bhesania for their assistance in conducting field testing procedures in their respective jurisdictions. Thanks also to the Baltimore, Maryland Department of Transit and Traffic for assistance in test sign fabrication.

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1.0 INTRODUCTION

From New England to Southern California and from the far Northwest to the southeastern shores of Florida, local jurisdictions have successfully converted unwarranted multiway stop-controlled intersections to less restrictive forms of control. This report is the result of a year-long research effort sponsored by the Federal Highway Administration (FHWA) which studied the conversion processes nationally. Throughout the course of the investigation, some thirty (30) separate jurisdictions, across the width and breath of this nation, were visited and information and data regarding the various conversion experiences were collected. Data from more than 170 separate intersections were studied by the research team in arriving at the conclusions and recommended procedures in this report. In addition to local government officials, several consultants in private practice, as well as professionals in quasi-public agencies, were interviewed and their experiences and knowledge of the conversion process incorporated appropriately throughout the report.

It is hoped that the experiences documented herein and the procedures recommended will serve to assist individuals and legislative bodies responsible for authorizing the installation and/or removal of traffic control devices, particularly stop signs, in arriving at the proper decision with regard to unwarranted stop signs. In addition, safe and prudent procedures are presented which hopefully will relieve some of the anxiety frequently associated with the removal of any traffic control device.

The emphasis of the study has been on the safety aspects of the conversion process. Fuel conservation and efficiency aspects have been well documented in past studies, some of which are cited in the bibliography.

1.1 STUDY OBJECTIVES

This study was undertaken with two primary objectives in mind:

1. To develop and test procedures to convert multiway stop sign-controlled intersections to two-way stop sign-controlled intersections.

2. To document the safety effects of converting multiway stop controls to two-way controls.

1.2 STUDY APPROACH

The general approach to the study was to visit at least 30 political jurisdictions which had multiway stop sign conversion experience. From their collective past experiences, and from methods which appeared to be reasonable, a recommended procedure was developed to convert multiway stop intersections to lesser forms of control.

1.3 REPORT ORGANIZATION

This report consists of two volumes. Volume I reports the results of the study undertaken leading up to the development of procedures with which to convert multiway stop intersections to lesser forms of controls. Volume II is devoted to presenting these conversion procedures in detail. Volume II is designed to stand alone as a useful reference document for the practicing traffic engineer, law enforcement official, local politician, or interested citizen.

2.0 BACKGROUND (Literature Search)

Over the past two or three decades, right-of-way control at many intersections has become multiway stop sign control. In some local jurisdictions, particularly those where elected officials and political appointees influence traffic engineering decision making, multiway stops are thought to be a panacea for intersection safety problems and speeding, promoting speed control, accident reduction, and pedestrian safety. Even though the Manual On Uniform Traffic Control Devices (MUTCD) has warrants for the application of multiway stop control, the "political" warrant, in some cases, is the only one that is met.

The following warrants for multiway stop signs are extracted from the MUTCD (19)*:

"The 'Multiway Stop' installation is useful as a safety measure at some locations. It should ordinarily be used only where the volume of traffic on the intersecting roads is approximately equal. A traffic control signal is more satisfatory for an intersection with a heavy volume of traffic.

Any of the following conditions may warrant a multiway STOP sign installation:

1. Where traffic signals are warranted and urgently needed, the multiway stop is an interim measure that can be installed quickly to control traffic while arrangements are being made for the signal installation.

2. An accident problem, as indicated by five or more reported accidents of a type susceptible of correction by a multiway stop installation in a 12-month period. Such accidents include right-and left-turn collisions as well as right-angle collisions.

3. Minimum traffic volume:

    (a) The total vehicular volume entering the intersection from all approaches must average at least 500 vehicles per hour for any 8 hours of an average day, and

    (b) The combined vehicular and pedestrian volume from the minor street or highway must average at least 200 units per hour for the same 8 hours, with an average delay to minor street vehicular traffic of at least 30 seconds per vehicle during the maximum hour, but

    (c) When the 85-percentile approach speed of the major street traffic exceeds 40 miles per hour, the minimum vehicular volume warrant is 70 percent of the above requirements."

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* References are included in the Bibliography, Appendix B.

The MUTCD States that stop signs should not be installed for speed control, but small cities and incorporated towns are frequent violators of the MUTCD warrants for the multiway stop controls. Research (8,9,20,54) has established that the installation of stop signs for the purpose of controlling vehicle speed does not achieve the desired result. Studies in the city of Troy, Michigan (9) and in Howard County, Maryland (54) revealed that placing stop signs for speed control actually increased vehicle speeds. Despite this fact, citizens frequently request the installation of stop signs to solve perceived traffic problems.

In 1977, the City Commission of Helena, Montana ordered installation of 10 four-way stop signs along two streets (one an arterial and the other a collector) in a residential neighborhood (31). The residents along these streets complained about growing traffic and perceived speed and safety problems to be significant on their streets. The before-and-after studies revealed that the installation of unwarranted four-way stop signs did not significantly reduce speeds, and a majority of motorists did not respect stop signs installed as a speed-control measure. The results of the before-and-after study in Helena clearly showed that the goal of increased traffic safety had not been realized.

Documented instances of local jurisdictions having implemented multiway stop sign removal programs is almost nonexistent. The very nature of the action, a local agency altering traffic control at a local intersection, does not lend itself to a large formal study. There may exist many successful methods, techniques, and experiences for converting multiway stop intersections to lesser forms of control that have not been widely publicized. A literature search can only reveal published sources, and a review of the available literature indicates there are many cities where multiway stop control is the predominant form of control at intersections. For example, in the city of Bloomington, Indiana, multiway stops exist on all types of intersections including arterials, collectors, and locals. In Philadelphia, more than 900 intersections are controlled by four-way stops. Philadelphia has now started to convert four-way stop control to other types of controls including signalization and two-way stops.

In 1974, the Missouri Automobile Association of America conducted a study in St. Louis that dealt mainly with the cost to motorists from unnecessary four-way stop signs (31). Over a period of many years, the city of St. Louis used four-way stops along arterial streets as interim measures until traffic signal warrants were met or until traffic signal funding could be obtained. When funding sources became scarce, however, these four-way stops remained in arterial streets for much longer than was originally intended. The Auto Club engineers investigated 44 arterial four-way stop signs located along major streets in St. Louis and found that these stop signs caused an additional 555,000 hours of travel time over the course of a year. This resulted in an increase of $1,623,000 in the operating cost of vehicles forced to stop at these signs. In addition, the Auto Club engineers estimated that an extra 1.5 million gallons of gasoline were consumed by using four-way stop signs on an arterial street.

Minneapolis, Minnesota has approximately 150 existing intersections controlled by multiway stop signs and has recently prepared a plan to remove unwarranted stop signs. Subject to the approval of the city council, approximately 30 of the existing 150 locations (about 20 percent) will be converted to two-way stop control.

Unwarranted stop signs increase stops, cause delays, and increase fuel consumption and pollutants. Further, installation of unwarranted traffic control devices breeds disrespect for such devices and can result in potentially dangerous behavior. For these reasons, it is desirable to remove unwarranted and unneeded stop signs which hinder traffic flow rather than aid it. In addition to the jurisdictions included in this study, many other cities in California, Illinois, Missouri, Ohio, Tennessee, and Wisconsin are in the process of removing unnecessary multiway stop signs.

These local jurisdictions are beginning to realize the mistakes of the past and understand that there are air pollution, delay, and energy impacts resulting from excessive use of multiway stops. As a result of this awareness, some cities have initiated studies and plan to convert multiway stop signs to two-way stop control (and occasionally to yield control). Peoria, Illinois initiated a program in the mid-1950's for the removal of unwarranted stop signs including four-way stops (23). As a result of their program, the number of four-way stops were reduced from 41 to 18. Of the 23 four-way stops removed, only one met minimum four-way stop warrants and that location was ultimately signalized. Peoria also found that the conversions won public support and improved driver obedience at "justified" stop signs.

Michigan Department of Transportation (MDOT) officials feel that unwarranted stop signs are undesirable for several reasons: such signs impede good traffic flow, waste energy (gasoline), encourage erratic mid-block driving, and breed disrespect for other, proper traffic signing (49). MDOT has a further interest in improved traffic flow because it acts as distributor of "Act 51" Maintenance funds to local communities. Act 51 funds are distributed to the communities based on the mileage of designated "major" and "local" streets within the communities. Streets that act as internal collectors to accommodate the major flow of traffic within a community are designated "major" and receive a higher funding rate than the minor roads. According to MDOT's Uniform Criteria for Major Streets, a community's road system should be signed to allow smooth traffic flow on major streets. If an accumulation of stop signs in a city prevents the designated major roads from carrying traffic smoothly, MDOT could reclassify the roads as "local" with a resulting 67 percent drop (approximate) in State maintenance funds for those roads.

For several decades, traffic engineering changes have, almost without exception, involved installing more positive or rigid control; for example, going from no control to two-way stop control or two-way to four-way stop control. Traffic engineers, as well as the general public, are conditioned to increasing the degree of control; we must approach the elimination of multiway stops with a strong public relations element if public acceptance is expected.

The process of conversion is never easy nor automatic. There are political and institutional constraints to overcome. Traffic engineers are concerned that pedestrian and vehicle accidents may increase. Recent computer simulation studies (62) indicate that this is a very real concern when certain traffic volumes, intersection designations, and approach speeds are combined. The project team was aware of the urgent need to develop a standardized multiway stop conversion methodology, one that minimizes the danger of increased accidents yet preserves the positive energy, economic, and environmental benefits.

The team understood that any procedure would have to include advance information notices, effective communications with the motorists approaching a converted intersection, and a period of time for conversions, enforcement requirements, and the collection of follow-up information. Additionally, critiques by practicing officials and field tests of recommended procedures were all envisioned as a part of the total research effort.

3.0 DATA COLLECTION

3.1 SELECTION OF STUDY LOCATIONS

Determining which political jurisdictions had at one time or another converted multiway stop intersections to lesser forms of control was neither an easy nor an automatic task. Though the automated literature search identified some of the more notable past activity in this area, lesser publicized, recent actions were not in the literature. Many other sources of information had to be relied upon to determine, to the greatest extent possible, which local jurisdictions had experienced the removal of unwarranted stop signs.

As an initial effort, notices were placed in national transportation and traffic journals and publicized at the annual meetings of the Institute of Transportation Engineers and the Transportation Research Board. Various technical committees and subcommittees were contacted, all with the same request assistance in identifying jurisdictions with conversion experience. Phone calls and letters were used to follow-up leads received from the team's queries. FHWA regions were contacted for assistance in determining activity in their respective areas of influence.

As a result of this grass roots search effort, more than forty political jurisdictions with relatively recent multiway stop sign conversion experience volunteered to provide information. With the approval of the Federal Highway Administration, the 31 jurisdictions indicated in Figure 1 were selected for site visits. Selection was based upon recent conversion experience, the availability of desired data and a good geographical cross section of urban areas and governmental agencies as determined from data voluntarily supplied by the jurisdictions in the format of Figure 2.

Each political jurisdiction selected for a site visit designated those intersections that had been converted from multiway stop sign control to lesser forms of control. Table 1 shows the number of intersections so identified.

Table 2 contains a breakdown by population of the cities and towns participating in the multiway stop sign study. Almost one-half of these jurisdictions had populations of less than 50,000 persons. These small urban areas often have a manager/council form of government and take on the characteristics of "bedroom communities." These cities, villages, and towns often cannot support a full time traffic engineer and hence traffic engineering matters are handled by the manager, police chief, city engineer or another individual so designated by the council. Interviews were conducted with 23 engineers/traffic engineers, 4 police officials, 6 managers, and 2 consultants. Technical support is provided by State or county personnel or outside private consultants. Matching Federal and State grants are the primary funding sources for traffic studies.

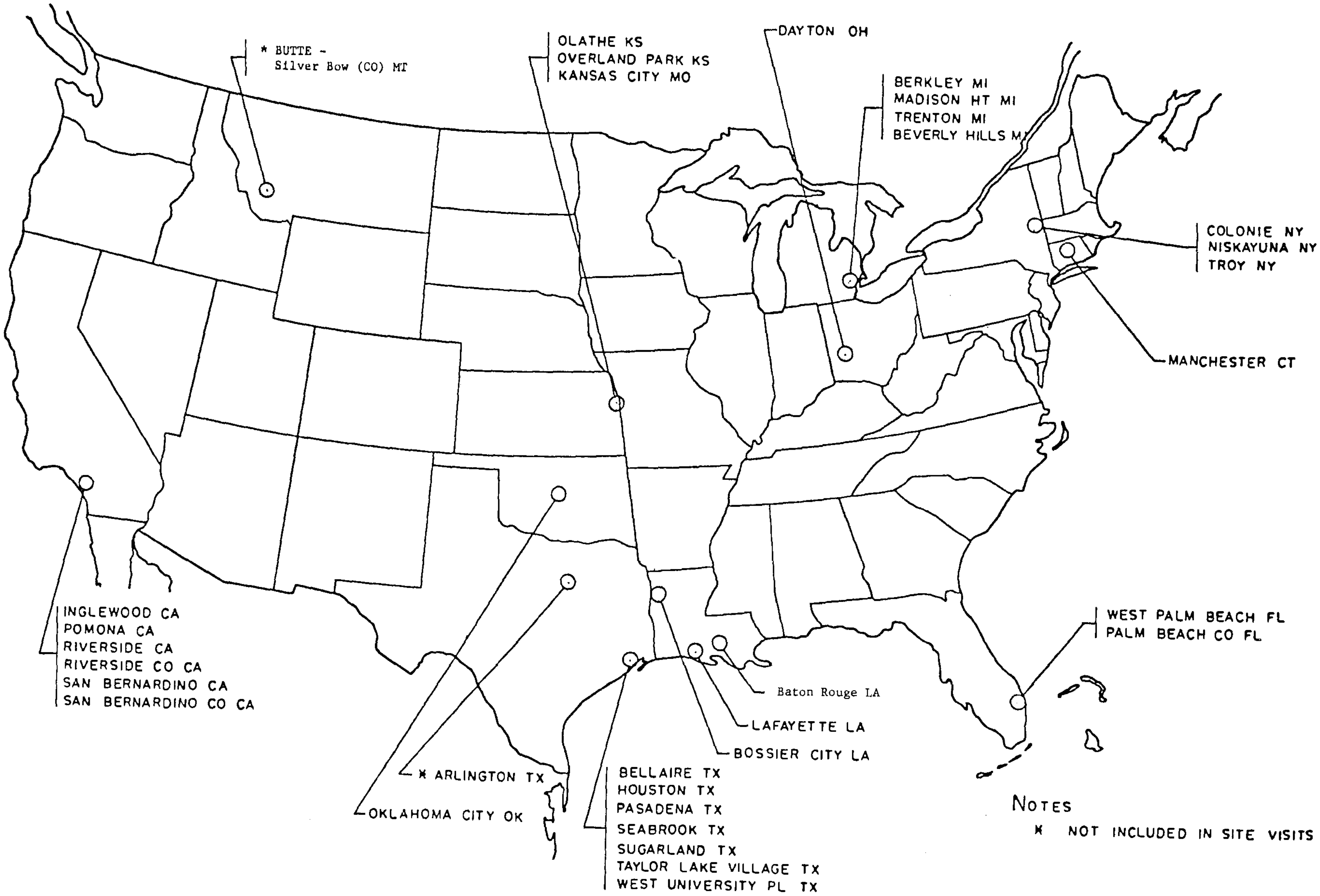

FIGURE 1. GEOGRAPHICAL LOCATIONS OF POLITICAL ENTITIES

"REMOVAL OF MULTIWAY STOP SIGNS WITHOUT HAZARD"

1. AGENCY ____________ City ____________ State ______

2. Number of intersections where multiway stop control has been changed to less restrictive control (for example, four-way to two-way, or two-way to no control, etc.).

3. Procedure followed to implement conversions: (Please provide sketches or samples where appropriate).

   - [ ] Installation of advance warning signs on intersection approaches. Please specify type of signs used.
   - [ ] Media Campaign: [ ] TV Spots [ ] Radio Spots
   - [ ] Newspaper Announcements
   - [ ] Citizen Involvement
   - [ ] Other Public Information Techniques used; please specify.

4. a. Was before and after data (specifically accidents, traffic volume, etc.) collected at the converted sites? [ ] Yes [ ] No

   b. Is before and after data available in ready-to-use format?

   [ ] Yes [ ] No

   c. Would this data be supplied on request? [ ] Yes [ ] No

5. What was public reaction to the conversion of controls?

   [ ] Favorable [ ] Adverse [ ] No Evaluated

6. Other Political Jurisdictions to your knowledge with conversion experience:

7. Additional information or comments, if any.

8. Point of contact for further information from your office/agency:

   Name: ____________ Phone: ____________

   Mailing Address: ____________

PLEASE RETURN COMPLETED FORM TO:

Mr. Claude M. Ligon, P.E.
AMAF Industries, Inc.
P.O. Box 1100
Columbia, Maryland 21044

FIGURE 2. FORM USED TO SCREEN POLITICAL ENTITIES FOR POSSIBLE SITE VISIT

TABLE 1. POLITICAL ENTITIES CONTRIBUTING TO MULTIWAY STOP SIGN STUDY

Political Entity	County/Parish	Population (000)	Number of Converted Intersections Studied
FHWA REGION 1			
Manchester, CT	Hartford	50	27
Colonie, NY	Albany	78	3
Niskayuna, NY	Schnectady	18	3
Troy, NY	Rensselaer	56	8
FHWA REGION 4			
Palm Beach County, FL	--	--	3
West Palm Beach, FL	Palm Beach	63	4
FHWA REGION 5			
Berkley, MI	Oakland	20	5
Beverly Hills, MI	Oakland	12	2
Madison Heights, MI	Oakland	35	5
Trenton, MI	Wayne	25	5
Dayton, OH	Montgomery	200	7
FHWA REGION 6			
Baton Rouge, LA	East Baton Rouge	250	2
Bossier City, LA	Bossier	55	20
Lafayette, LA	Lafayette	82	2
Oklahoma City, OK	Oklahoma	450	2
Arlington, TX *	Tarrant	160	6
Bellaire, TX	Harris	15	3
Houston, TX	Harris	1500	3
Pasadena, TX	Harris	120	3
Seabrook, TX	Harris	5	2
Sugarland, TX	Fort Bend	9	15
Taylor Lake Village, TX	Harris	4	4
West University Place, TX	Harris	12	2

* Not included in site visits.

TABLE 1. POLITICAL ENTITIES CONTRIBUTING TO MULTIWAY STOP SIGN STUDY (continued)

Political Entity	County/Parish	Population (000)	Number of Converted Intersections Studied
FHWA REGION 7			
Olathe, KS	Johnson	39	4
Overland Park, KS	Johnson	82	4
Kansas City, MO	Jackson	448	5
FHWA REGION 8			
Butte-Silverbow, MT *	Silverbow	37	9
FHWA REGION 9			
Inglewood, CA	Los Angeles	90	4
Pamona, CA	Los Angeles	100	2 **
Riverside, CA	Riverside	171	2
Riverside County, CA	--	--	2
San Bernardino, CA	San Bernardino	130	6
San Bernardino County, CA	--	--	1 **

* Not included in site visits.
** Accident data not available.

TABLE 2. POPULATIONS OF STUDY CITIES/TOWNS

Population (P)* Range	Number of Study Cities/Towns	Percent of Total Cities/Towns
$P < 50,000$	13	43
$50,000 < P < 100,000$	8	27
$100,000 < P < 500,000$	8	27
$1,000,000 < P$	1	3
TOTAL	30	100

* Populations of 3 counties studied not included.

The personalities and working relationship between the individuals on the council and the person serving as the local traffic engineer will to a great degree determine the success of the traffic engineering program. Though valid warrants might be applied and certain actions justified as a result, the degree to which local citizens can persuade the council will often be the final determining warrant. It is therefore extremely important that the council and citizens be informed, educated, and convinced of the need for the recommended traffic engineering improvements. Citizens consider themselves as the traffic experts for their immediate neighborhoods and are wary of "outsiders" who do not have a personal stake in the local traffic situation.

Average daily traffic (ADT) and the posted speeds of the converted intersections studied are indicated in Tables 3 and 4, respectively. The fact that over one-half of the converted intersections had ADT's of less than 1500 vehicles per day and posted speeds of 25 miles per hour or less suggest that most conversions identified in this study had been accomplished at residential intersections. This is often where complaints of speeding are most common and the "political warrant" for multiway stop sign installation is exercised. This situation often creates a climate for wholesale stop sign removals when subdivisions are annexed by a larger urban area. Subdivisions often use stop signs as speed control devices.

3.2 ACQUISITION OF DATA

At every jurisdiction, data were obtained by either telephone conversations, written correspondence, person-to-person interviews, intersection visits, and record searches or combinations of the foregoing.

Accident reports were requested. When not available, substitutes such as traffic studies or number of accidents were used. Figure 3 was used as a guide for the on-site data collection effort. Availability of information varied widely; records were often not available for an intersection of interest. Examples of this would be accident reports not available because of the time lapse since the intersection was converted, traffic volume data not available because it was not a routine element in the traffic program of all jurisdictions visited, actual date of conversion not known in all instances, etc.

Data were collected by way of on-site visits during the period December 1982 through March 1983. At the time of visits not all jurisdictions had actual conversions in progress, hence "NOTICE" or "CAUTION" signs that might have been used were not in place. Those signs in place were photographed.

3.3 HIGHLIGHTS OF SITE VISITS

MICHIGAN

TRENTON

The City Council of Trenton, Michigan approves all installations and removals of stops by a change to the local ordinance. This is accomplished by inviting citizen input and holding public hearings. The result of the council's deliberation is published in the council's minutes of the meetings. If a stop sign removal is approved, an announcement is made in the local newspaper 7 days prior to the actual removal. Press coverage by the local news tends to also publicize the pending conversion.

TABLE 3. AVERAGE DAILY TRAFFIC (ADT) OF CONVERTED INTERSECTIONS

Total Intersection ADT Range	Number of Converted Intersections Studied	Percent of Total Intersections
< 1,500	98	57
1,500 - 3,000	32	19
> 3,000	42	24
TOTAL	172	100

TABLE 4. POSTED SPEEDS OF CONVERTED INTERSECTIONS

Speeds (mph)	No. of Intersections Posted	Percent of Total Intersections
20	6	3
25	101	59
30	49	29
35	6	3
40	9	5
50	1	1
TOTAL	172	100

"REMOVAL OF MULTIWAY STOP SIGNS WITHOUT HAZARD"

DATA COLLECTION FORM

STATE ____________________ FHWA REGION ________ DATE ______

CITY ____________________ COUNTY ________________

POPULATION ______________

INTERSECTION: (STUDY) ____

DATE OF CONVERSION ________________

LAND USE: COMMERCIAL ___ RESIDENTIAL ___

EDUCATIONAL ___ OTHER ___

DENSE ___ SPARSE ___ RURAL ___ URBAN ___

GEOMETRICS: LAYOUT PLAN ATTACHED ___

SKETCH ATTACHED ___

ROADWAY FUNCTIONAL CLASSIFICATION:

	ARTERIAL	COLLECTOR	LOCAL
MAJOR			
MINOR			
OTHER			

HISTORICAL DATA ON INTERSECTION
(TO INCLUDE DATE OF CONVERSION)

CONTROL INTERSECTION ____

TRAFFIC DATA:

VOLUMES:

- VEH MIX
- TURNING MOVEMENT
- PEAK
- PEDESTRIANS
- NON-PEAK

SPEEDS (MIDBLOCK) (OR SPEED LIMIT)

- BEFORE
- AFTER
- EACH APPROACH

DELAY STUDIES

STOPPING COMPLIANCE STUDIES

- BEFORE/AFTER
- DOCUMENTED OBSERVED

FIGURE 3. GUIDE FOR ON-SITE DATA COLLECTION

ACCIDENT DATA (1 YEAR BEFORE AND AFTER)

STUDY SITE

CONTROL SITE(S)

RÈPORTS AVAILABLE?

CONVERSION PROCEDURES (WRITTEN PROCEDURES AVAILABLE TO US)

- STUDIES
- ADVANCE PUBLIC NOTIFICATION

  MEDIA (TV, RADIO, NEWSPAPER)

  CITIZENS' FORUMS

  SIGNS ON SITE

  OTHER

- IMPLEMENTATION

  PHYSICAL REMOVAL OF SIGNS

  ADDITIONAL WARNING SIGNS ERECTED

  TRAFFIC ENGINEER MONITORING

  ENFORCEMENT

- JUSTIFICATION FOR CONVERSION (REASONS FOR)
- PROBLEMS
- CRITIQUE BY DIFF GROUPS

LIABILITY AND LEGAL ACTIVITIES

CLAIMS PRIOR TO AND AFTER CONVERSION

POLICY FOR INSTALLING SIGNS IN GENERAL (FOUR-WAY STOPS HAVE DIFF POLICY?)

PHOTOGRAPHS: ROLL # ____ FRAME(S) # ____

POINT OF CONTACT:

NAME: ______________________ PHONE: ______________

MAILING ADDRESS ______________________

____

____

FIGURE 3. GUIDE FOR ON-SITE DATA COLLECTION (continued)

Actual removal of unwarranted stop signs is preceded by a detailed traffic study at the intersections which contained multiway stop signs. Primary reasons for removal of stop signs from these locations were the absence of the pedestrian and vehicle traffic to satisfy minimum multiway stop sign volume warrants and the presence of multiway stops at adjacent intersections. In some instances, the minor street was only two blocks in length.

Stop signs are removed for a 90-day trial period. No advance warning signs are used at the intersection, but supplementary CAUTION signs are posted beneath the remaining stop signs for a period of 90 days (Figures 4 through 6). Additionally, stop lines and parking restrictions are used to increase safety at the converted intersection. Traffic counts and speed surveys are conducted and the accident experience is monitored at converted intersections. These studies support recommendations for traffic control at the intersection following the 90-day trial period. In some instances, stop signs have been reinstalled after citizens petitioned the city council.

BERKLEY

Berkley, Michigan felt that the way to begin multiway stop sign conversions was to thoroughly educate the citizens and council regarding the recommended action. Technical support was obtained from the American Automobile Association (AAA), private consultants, State and Federal personnel, and certain non-profit groups. This could be a long, drawn out process as in most cases action is being requested to remove a traffic control device which has been in place, justified or not, for years. Once the need for the requested traffic engineering change is realized by the citizens and council, actual removal can proceed smoothly. Since the neighbors directly affected by the multiway stop sign removal have been involved at every step along the way, further notices had been found to be unnecessary and the designated sign and posts are removed immediately. Once removed using this process, there were few complaints or requests for reinstallation of the stop signs.

Berkley, Michigan removed more than 100 stop signs from its town streets in conjunction with a general upgrading of traffic signs. Studies were initiated in 1979, approvals were sought from the town council in 1980, and the removal of stop signs actually occurred in 1981. During the first year of removals, accidents dropped from an average of 550 per year to an average of 250 per year. Town police issued 50 percent fewer traffic citations during a corresponding period of time.

Public meetings of 100 or more persons in Berkley neighborhoods served to alert the general public of the upcoming stop sign removal campaign. With this mass publicity campaign preceding the actual removals, supplementary notice or caution signs were not thought to be necessary and hence not used. The post conversion accident experience in Berkley suggests that citizen involvement before conversion was an effective notice vehicle. Figure 7 depicts a typical residential four-way stop intersection in Berkley, Michigan prior to conversion to a two-way stop-controlled intersection. Figure 8 shows a residential collector which had the flow of traffic made more efficient by the removal of unwarranted stop signs.

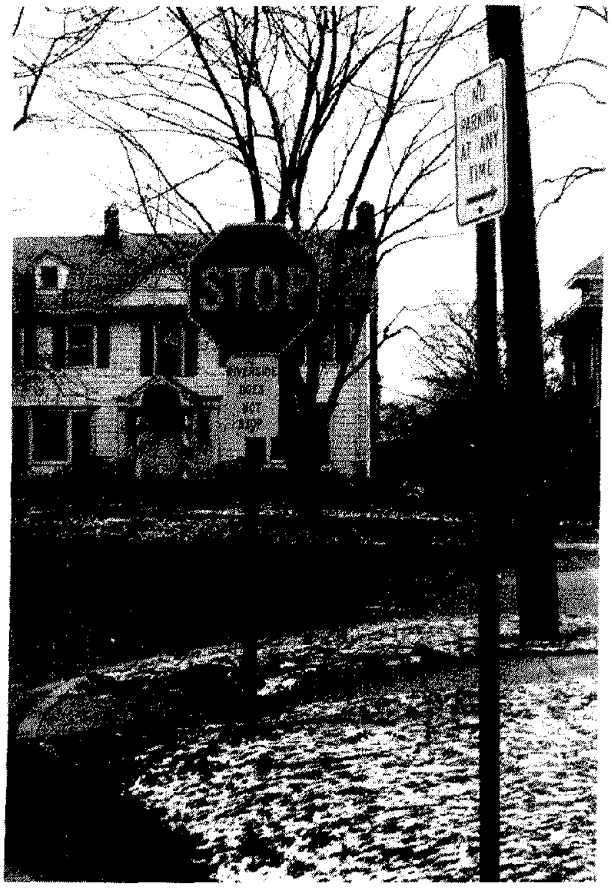

FIGURE 4. SUPPLEMENTARY SIGN AT T-INTERSECTION AFTER CONVERSION. (Note parking restriction to improve visibility.) (TRENTON, MICHIGAN)

FIGURE 5. SUPPLEMENTARY SIGN AT 4-LEGGED INTERSECTION AFTER CONVERSION. (TRENTON, MICHIGAN)

FIGURE 6. SUPPLEMENTARY SIGN AT T-INTERSECTION AFTER CONVERSION. (Text of sign as in Figure 5. Note use of stop line.) (TRENTON, MICHIGAN)

FIGURE 7. TYPICAL 4-LEGGED, MULTIWAY STOP INTERSECTION STUDIED. (BERKLEY, MICHIGAN)

FIGURE 8. RESIDENTIAL COLLECTOR WHICH HAD 4 OF 16 INTERSECTIONS CONVERTED FROM 4-WAY TO 2-WAY STOP CONTROL. (BERKLEY, MICHIGAN)

BEVERLY HILLS

Local warrants were established in Beverly Hills, Michigan to be used in conjunction with those contained in the MUTCD. Multiway stop signs at a given intersection are considered warranted if that intersection (1) is adjacent to a school, (2) is along a school route, (3) has sight distance problems which cannot be corrected by other means, and/or (4) has a "difficult" configuration. The Village Council must pass an ordinance to install or remove a traffic control device. Advance notice of pending stop sign removals is by way of local newspapers and citizen forums sponsored by the village council.

MADISON HEIGHTS

Madison Heights, Michigan, like many of its neighboring communities in the Greater Detroit Metropolitan area, tied its stop sign removal program to the Federal and State sign upgrading program. The experiences of this community indicated that stop sign removals are best accomplished in the winter months. It was felt that during this period, out-of-doors activity was lowest and hence motorist-motorist and motorist-pedestrian conflicts were minimized with respect to intersection conversion activity. Another practice found to be successful here was to remove the stop sign, leave the post in place, and then remove the post in about 2 weeks.

On one occasion in Madison Heights, a citizen group submitted a petition with many signatures requesting reinstallation of stop signs at an intersection in their neighborhood. The town council sent the request to the Traffic Safety Committee which consisted of the police chief, fire chief, director of public works and the town engineer. The Traffic Safety Committee recommended against reinstallation on the grounds that (1) multiway stop signs do not reduce accidents, (2) neighbors in the vicinity of the disputed intersection constituted the largest number of stop sign violators as documented on 8 mm film, which included sound for effect, (3) unwarranted stop signs do not reduce speed, and (4) the community noise level increases with the increase in vehicle stops caused by the unwarranted stop signs.

TEXAS

HOUSTON

In Houston, Texas, installation of all-way (multiway) stops is based on the Texas Manual on Uniform Traffic Control Devices. Removals are frequently tied to annexations of subdivisions. However, some all-way (multiway) stops are installed as a result of public and political pressures. Removal of all-way stops is extremely difficult due to public perception and political pressure.

The City of Houston's Code of Ordinances specifies that all traffic control devices be in compliance with the Texas MUTCD. Therefore, they are legally bound to follow the manual when removing or installing all-way stops. To date, there had been no legal action taken against Houston for removal of all-way stops.

Houston has no written procedure for removing all-way stops. However, generally an investigation is made that includes field observations, traffic counts, and review of accident experience. Based on this data, the decision is made to retain or remove the all-way stop and the installation of the appropriate traffic control devices. In most cases, all-way stops are replaced with two-way or one-way stops controlling the minor streets. In each case of removal in 1981, no warning signs were used in advance, and there was no public notification. Signs stating "NOT A FOUR-WAY STOP" were installed below the stop signs at two of the locations where the all-way stops were removed.

Follow-up studies are generally limited to on-site observation as any immediate change in accident experience is considered short term, and the reevaluation based on accidents should be done after the adjustment period. No speed, delay, or compliance studies were performed at these intersections.

BELLAIRE

A "TEMPORARY" supplemental plate (Figure 9) is used by Bellaire, Texas to indicate which stop signs are unwarranted and subject to removal in the near future. Adjacent construction activity was cited as a reason for having to remove stop signs. This construction justification was cited by both Pasadena, Texas and Pamona, California. Once unwarranted stop signs are removed, the supplementary caution signs in Figure 10 are mounted beneath the remaining stop signs at the intersection to inform motorists of the change in traffic control.

PASADENA

The Traffic Commission in Pasadena consists of citizens and city staff members in equal numbers. The city traffic engineer has been granted the authority to remove traffic signs, but his actions are coordinated with the traffic commission. In some instances, Texas jurisdictions have not outright removed multiway stop signs but have reversed the right-of-way at a stop sign-controlled intersection, hence precipitating a stop sign removal action.

The stop sign reversal procedure involves a four-way stop for one week prior to reversal with "TEMPORARY" supplemental plates below each "FOUR-WAY" plate. For one week following the reversal (removal of previous two stop signs, four "FOUR-WAY" plates, four "TEMPORARY" plates), a black on yellow (24" diamond) warning sign is installed beneath each of the remaining two stop signs. The message on these signs is "NOT A FOUR-WAY STOP." (See signs for Bellaire, Texas in Figures 9 and 10.)

HOUSTON, SEABROOK, AND SUGARLAND

As in the case of Houston, other Texas towns such as Seabrook and Sugarland, often tie their stop sign removals to the annexation of a subdivision. In a recent annexation by Sugarland, all existing multiway stops in the subdivision were removed as being unwarranted. The traffic engineer has the authority to install and remove traffic control devices. By the residential nature of the intersection involved, with low volumes and low speeds, Sugarland simply removed the unwarranted stop signs without any attending outcry or accidents.

FIGURE 9. USE OF "TEMPORARY" SUPPLEMENTARY SIGN PRIOR TO REMOVAL OF STOP SIGN. (BELLAIRE, TEXAS)

FIGURE 10. CANDIDATE SUPPLEMENTARY CAUTION SIGNS FOR POSTING BENEATH REMAINING STOP SIGNS. (Black letters on yellow background.) (BELLAIRE, TEXAS)

TAYLOR LAKE VILLAGE

Taylor Lake Village, Texas was one of four local jurisdictions visited which had its traffic engineering matters handled by the police department augmented as necessary by outside consultants. In Taylor Lake Village, the city council passes ordinances regarding the installation and removal of traffic control devices. Because of the size of the town, the smallest visited during the course of this study (population 4,000), the chief of police is able to send letters to all households regarding proposed changes in traffic control in the town.

WEST UNIVERSITY PLACE

This notification action in Taylor Lake Village is contrasted by West University Place, Texas. This larger jurisdiction uses monthly water bill mailings to publish pending stop sign removal actions. The disadvantage here is thought to be that the entire town is made aware of a potentially volatile issue which directly affects perhaps only one neighborhood. The chances for adverse public reaction to the stop sign removals is increased.

KANSAS

OVERLAND PARK

Overland Park, Kansas converted a multiway stop to a two-way stop on March 19, 1970 and observed the reaction of motorists to the conversion. Approximately 40 percent of the motorists using the through street stopped unnecessarily at the intersection where they had been accustomed to stopping. Five days later, this figure dropped to only 5 percent, similar multiway conversions in the same vicinity resulted in almost identical behavior.

At a similar converted intersection in Overland Park, three accidents were recorded in the month following the conversion. After this period of adjustment, however, there were no accidents in the next five months. It was the judgement of the local traffic engineer that the sight distance at the intersection could sustain the normal 35 mph speed limit but would prove hazardous if traffic exceeded 40 mph. He believed the removal of the stop signs were warranted but forewarned of the potential hazard at other converted intersections.

OLATHE

In 1979, Olathe, Kansas conducted vehicle counts at all multiway stop intersections in that town. A formal report was rendered by the traffic engineer which resulted in several conversions. After conversions, the 2-way and caution supplementary plates shown in Figure 11 were posted beneath the remaining stop sign(s).

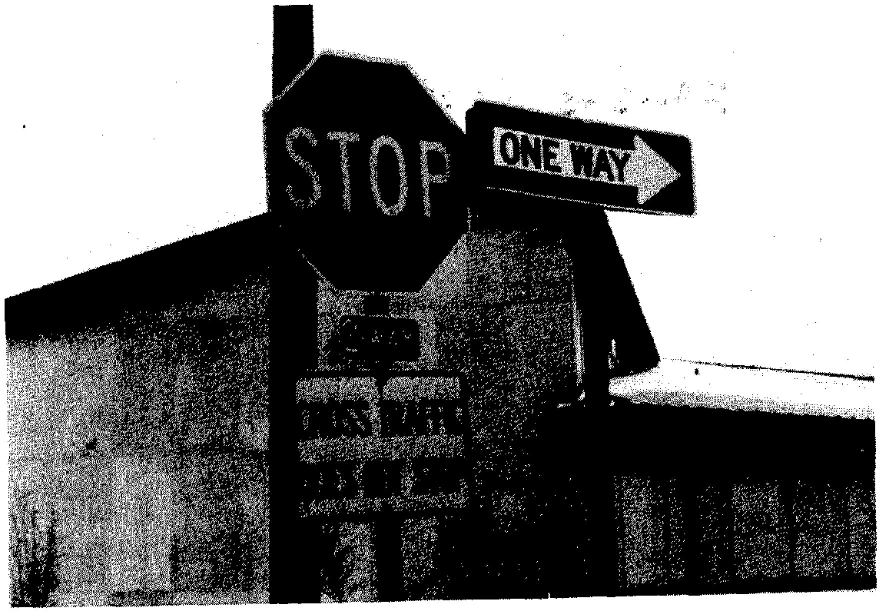

FIGURE 11. SUPPLEMENTARY SIGN WITH TWO-WAY SUPPLEMENTAL PLATE AFTER CONVERSION. (OLATHE, KANSAS)

MISSOURI

KANSAS CITY

When a stop sign is determined to be unwarranted by traffic engineering studies, Kansas City, Missouri has an ordinance passed by the city council authorizing the removal. Letters are sent to residents of the affected neighborhood by the Director of Aviation and Transportation (Figure 12). After conversion, Kansas City uses a supplemental sign bearing the message "CROSS TRAFFIC DOES NOT STOP," beneath the remaining stop sign(s) (Figure 13). Kansas City, uses other appropriate traffic signs and techniques to correct situations before installing multiway stop signs as a last resort. Kansas City consented to participate in field tests involving procedures developed by this research; these field tests are discussed in Chapter 7.

OKLAHOMA

Oklahoma City, Oklahoma recognized a need to facilitate entrance onto a city arterial by residents of a particular development once stop signs were removed from that arterial. In addition to posting caution signs, an exclusive left turn lane was added (Figure 14). The caution sign used by this jurisdiction is indicated in Figure 15. After removal of stop signs, two days of law enforcement by the local police is requested with citations issued. The installation and removal of traffic control devices is authorized by a city traffic commission consisting of a representative of the police department, each of 8 city wards, and one at-large representative, all appointed by the city council.

Transportation Department
Office of the Director

City of Kansas City, Missouri
Heart of America

23rd Floor, City Hall
Kansas City, Missouri 64106

816/274-1625

September 26, 1983

TO: Residents of 7800 and 7900 Blocks of Ward Parkway Plaza
FROM: Delbert F. Karmeier, Director of Aviation & Transportation

****

One of the objectives established by our Traffic Control Division for 1983 is to remove unnecessary "Stop" signs. The elimination of unnecessary "Stop" signs reduces delays, saves fuel and improves the attitude of motorists towards traffic control devices. Kansas City has also been invited to participate in a national demonstration program being conducted by the Federal Highway Administration relating to the removal of unnecessary "Stop" signs.

Traffic counts made on September 14, 1983 showed that a total of 5,709 vehicles per day used the intersection of Ward Parkway Plaza and 79th Street with 74 percent of the traffic on 79th Street. Observations made on September 15, 1983 from 7-8 a.m., 11 a.m. to 12 p.m. and 4-5 p.m. showed that only ten pedestrians were observed at 79th Street and Ward Parkway Plaza. Motorists on Ward Parkway Plaza have unrestricted visibility of traffic on 79th Street.

Traffic at the intersection is presently controlled by "Stop" signs on both 79th Street and Ward Parkway Plaza. The study shows that only one-fourth of the motorists entering the intersection use Ward Parkway Plaza. Therefore, it is proposed that the "Stop" signs for motorists on 79th Street be removed for a 90-day trial period and that "Cross Road Traffic Does Not Stop" signs be temporarily installed for motorists on Ward Parkway Plaza.

A regulation providing temporary removal of "Stop" signs on 79th Street will be published within the next 15 days. The signing changes will then be made on Tuesday, November 1, 1983. Your assistance in advising motorists in your home of these changes will be appreciated.

Very truly yours,

Delbert F. Karmeier

Delbert F. Karmeier
Director of Aviation & Transportation

DFK:RPB:mat

FIGURE 12. SAMPLE LETTER SENT TO RESIDENTS OF KANSAS CITY, MISSOURI

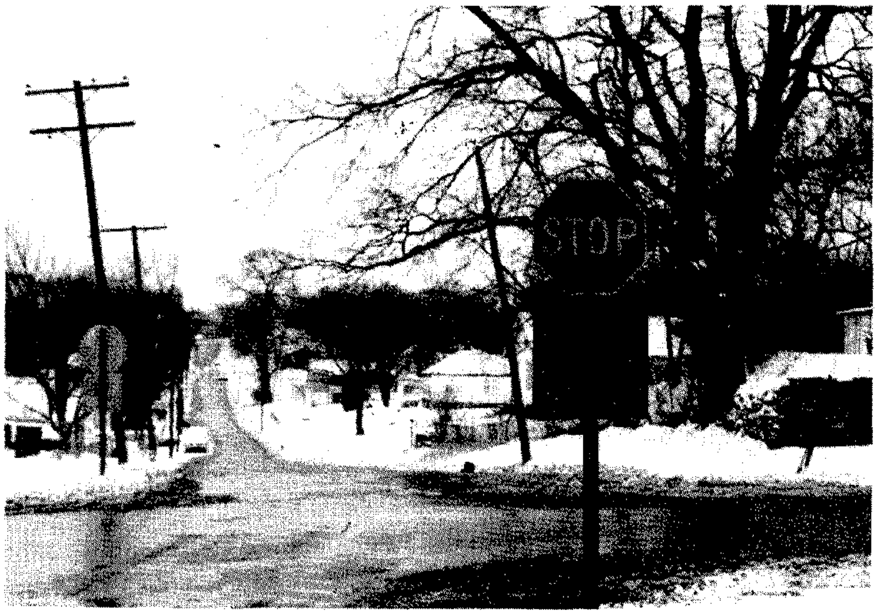

FIGURE 13. SUPPLEMENTARY SIGN AFTER CONVERSION. (Note supplementary sign on post on opposite corner.) (KANSAS CITY, MISSOURI)

FIGURE 14. SUPPLEMENTARY SIGNS BENEATH TWO REMAINING STOP SIGNS AFTER CONVERSION. (See also Figure 15. Note addition of left turn lane to increase intersection capacity.) (OKLAHOMA CITY, OKLAHOMA)

FIGURE 15. SUPPLEMENTARY SIGN AFTER CONVERSION. (OKLAHOMA CITY, OKLAHOMA)

OHIO

DAYTON, OHIO

Upon converting a multiway stop intersection, Dayton, Ohio will post a "Two-Way" supplementary plate beneath the remaining two stop signs. A plywood message board is used to hold a caution message warning motorists of the change. The temporary nature of the materials, and the placement of the message board on the sidewalk just prior to the intersection render it vulnerable to vandalism (Figure 16).

LOUISIANA

BATON ROUGE/LAFAYETTE

Baton Rouge, Louisiana is a jurisdiction which employed signs on location to warn motorists of a pending change in traffic control at a given intersection. Baton Rouge used the notice sign depicted in Figure 17 thirty days prior to accomplishing a stop sign removal action. On the other hand, Lafayette used the signs in Figures 18 and 19 to facilitate a reassignment of right-of-way at a given intersection. This action obviously involves the installation of, as well as removal of, stop signs. For pure removal actions, Lafayette posts the "STOP SIGN TO BE REMOVED" sign 30 days before the conversion. On the day of removal, a "CROSS STREET DOES NOT STOP" sign is posted. The Lafayette City Council delegates traffic control device installation and removal authority to the director of public works.

BOSSIER CITY

Bossier City, Louisiana does not use supplementary signs for the conversion process. The technique used here to alert the motorists of change is to substitute a 30" stop sign for the remaining 24" stop sign and install a stop line at all converted multiway locations. After a period of time, the 24" stop sign is reinstalled.

FIGURE 16. SUPPLEMENTARY TWO-WAY PLATE USED AFTER CONVERSION. (Note sign message board to right of photograph which is used to hold pre-conversion supplementary messages.) (DAYTON, OHIO)

FLORIDA

WEST PALM BEACH

Local residents, as often is the case, were found to be the cause of an increase in accidents at a converted intersection in West Palm Beach, Florida. After a nearby major industrial complex ceased operation, local motorists sensing the reduction in traffic volumes, began to usurp the right-of-way from opposing motorists at this four-way stop sign-controlled intersection, thereby causing conflicts. The West Palm Beach traffic engineer has the authority to install and remove traffic control devices.

PALM BEACH COUNTY

Palm Beach County, Florida uses a "CAUTION, NO FOUR-WAY STOP" beneath remaining stop signs for a 60-day period after converting the intersection's form of traffic control (Figure 20).

CALIFORNIA

INGLEWOOD

Energy conservation was the major impetus for removing unnecessary stop signs in the city of Inglewood, California. The supplementary sign shown in Figure 21 is posted by the traffic engineer beneath remaining stop signs. The traffic engineer has the authority to install and remove traffic control devices based on recommendations of a parking and traffic commission.

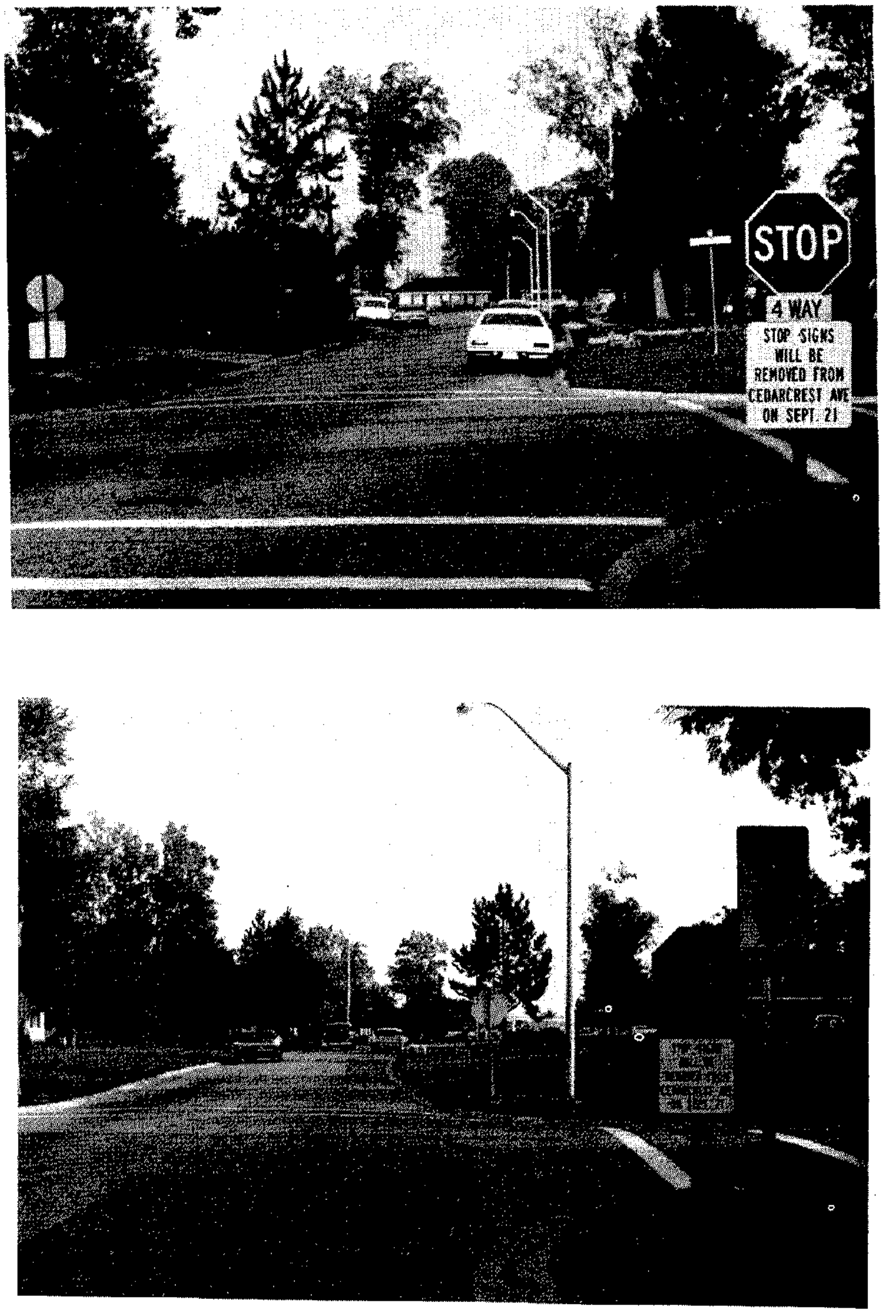

FIGURE 17. SUPPLEMENTARY NOTICE SIGN
(BATON ROUGE, LOUISIANA)

FIGURE 18. EXAMPLE OF ADVANCE MOTORISTS WARNING
(LAFAYETTE, LOUISIANA)

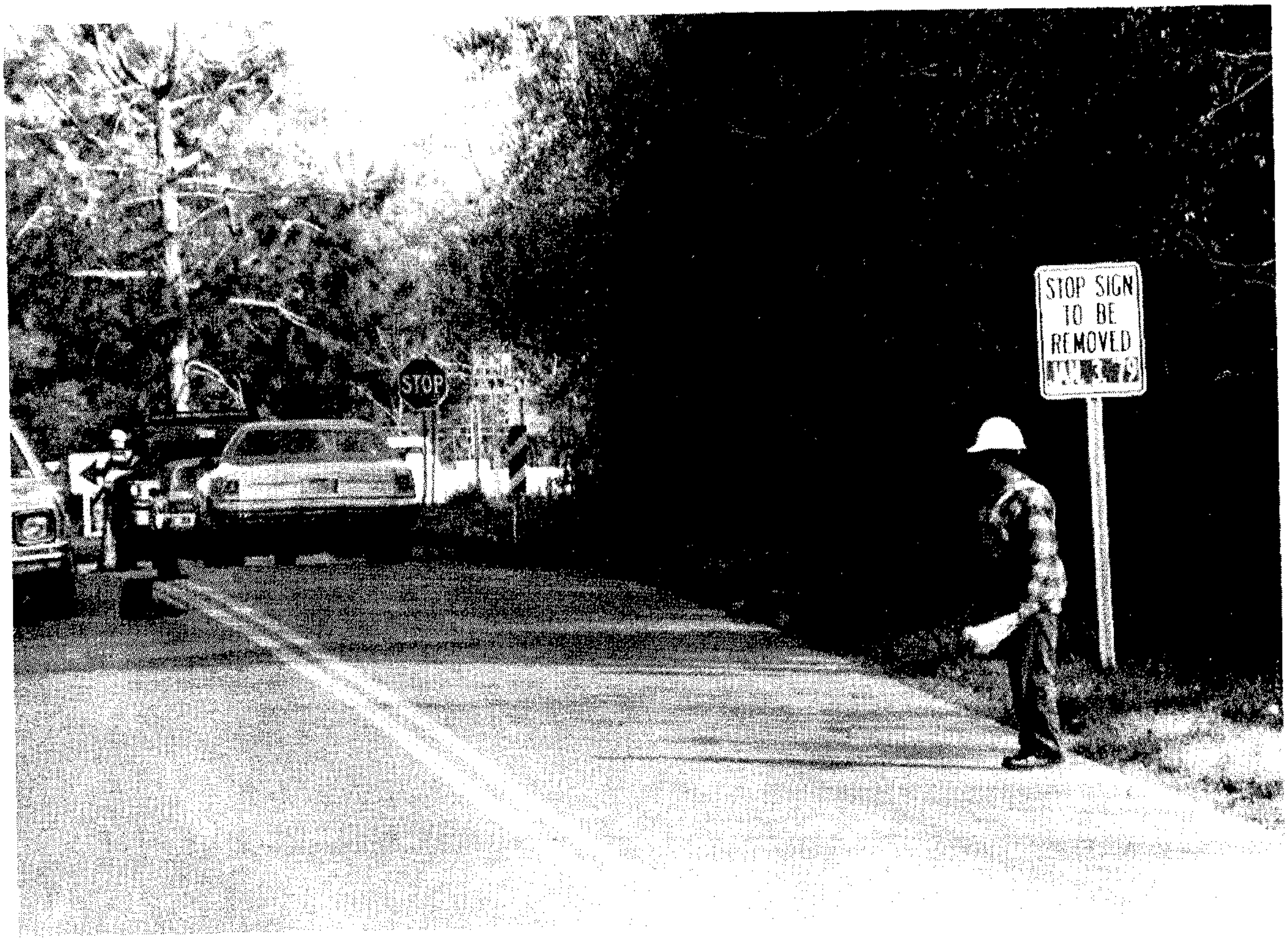

FIGURE 19. EXAMPLE OF ADVANCE MOTORISTS WARNING
(LAFAYETTE, LOUISIANA)

FIGURE 20. SUPPLEMENTARY SIGN AFTER CONVERSION
(PALM BEACH COUNTY, FLORIDA)

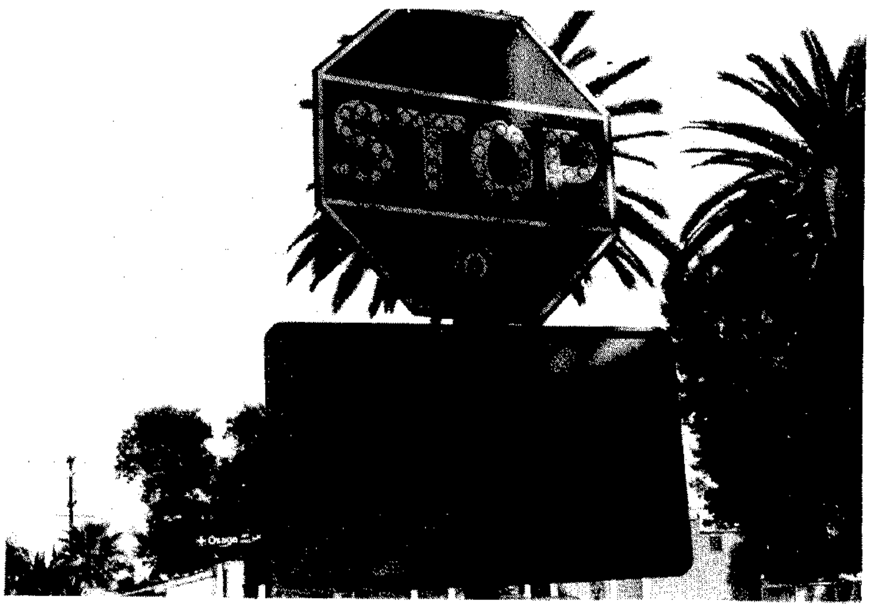

FIGURE 21. SUPPLEMENTARY SIGN AFTER CONVERSION
(INGLEWOOD, CALIFORNIA)

RIVERSIDE

Riverside, California, as a part of its conversion program, removes all applicable pavement markings as well as unwarranted stop signs. A police officer is stationed at the intersection on the day of conversion to observe the effect of conversion on motorists' behavior. In some instances, stop signs were reinstalled years later. This jurisdiction conducted a detailed study concerning the safety effects of pavement markings.

RIVERSIDE COUNTY

The supplementary sign in Figure 21a is used by Riverside County, California after converting an intersection. In addition to supplementary signs used directly beneath the remaining stop sign(s), Riverside County uses stop lines and pavement legends to assist in emphasizing the requirement to stop on a particular approach (Figure 22). Where a sight distance problem exists with respect to the remaining stop signs at the intersection, the supplementary signs in Figure 23 are used in advance of the intersection. Stop line removal is also an integral part of this conversion process.

SAN BERNARDINO

As in the case of Riverside County, California, San Bernardino uses a stop line and pavement legend after conversion (Figure 24) in addition to the supplementary sign beneath the remaining stop sign(s). The message used here is "CROSS TRAFFIC DOES NOT STOP." San Bernardino received complaints of speeding on the through street.

SAN BERNARDINO COUNTY

San Bernardino County, California, the largest county in terms of geographical area in the United States, places extra emphasis when converting intersections in some of the outlying, sparsely populated sections of the county. Figure 25 depicts the use of back-to-back supplementary signs beneath each remaining stop sign. Additionally, pavement legends and "STOP AHEAD" signs are used to further emphasize the existence of the remaining stop signs (Figure 26).

NEW YORK

COLONIE

In Colonie, New York, where the police department has responsibility for traffic matters, the availability of Federal-Aid "402" funds was the catalyst for implementing an unwarranted stop sign removal program. The town highway safety commission makes recommendations to the town council which in turn authorizes the installation and removal of traffic control devices.

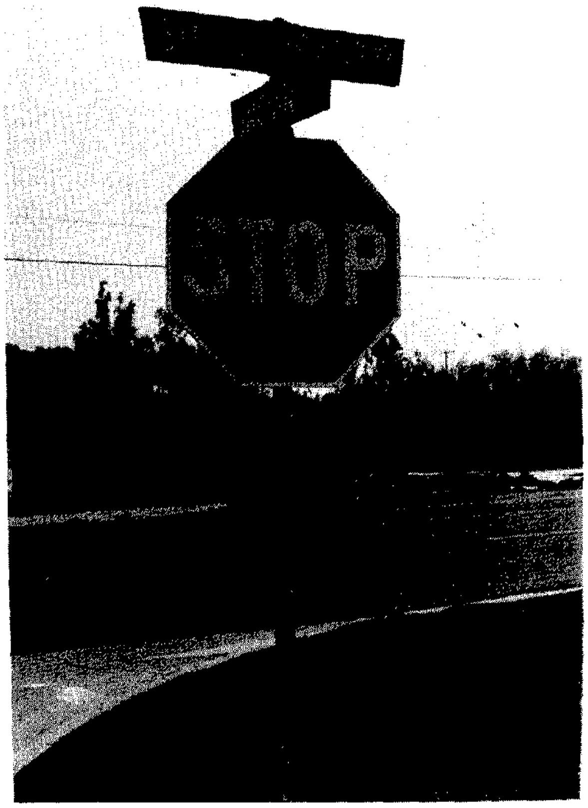

FIGURE 21a. SUPPLEMENTARY SIGN AFTER CONVERSION (RIVERSIDE COUNTY, CA)

FIGURE 22. USE OF SUPPLEMENTARY SIGN WITH STOP LINE AND PAVEMENT LEGEND AFTER CONVERSION. (See also Figure 1.) (RIVERSIDE COUNTY, CA)

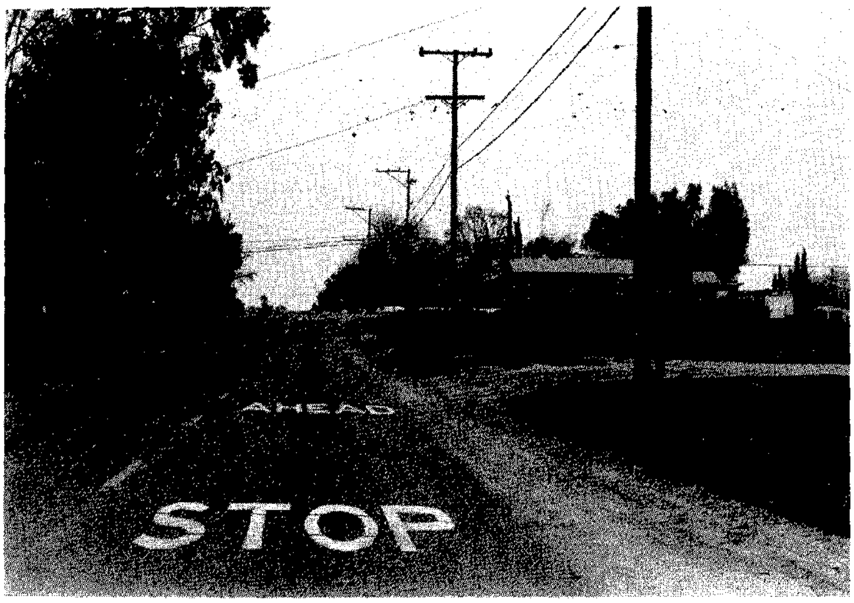

FIGURE 23. "STOP AHEAD" SYMBOL SIGN USED WITH SUPPLEMENTARY WORD MESSAGE AND PAVEMENT MARKING. (RIVERSIDE COUNTY, CALIFORNIA)

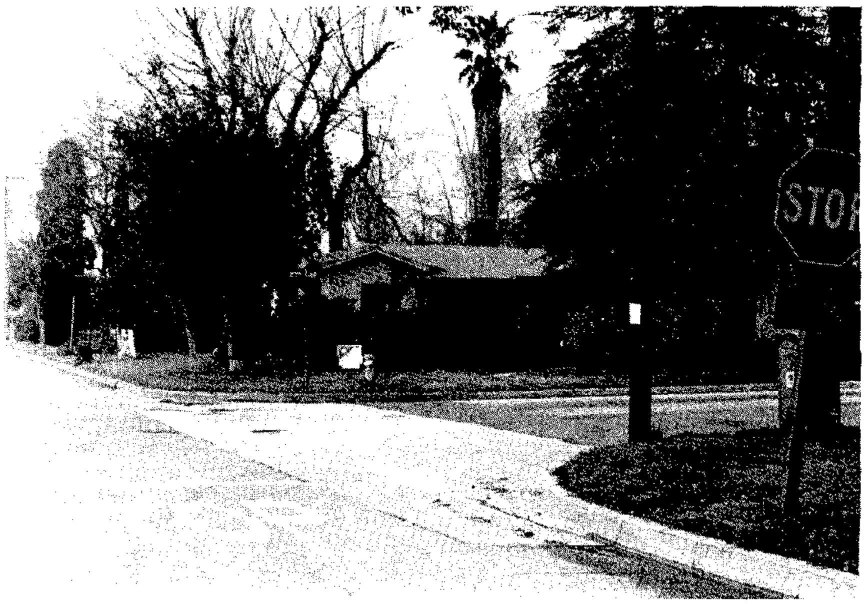

FIGURE 24. USE OF SUPPLEMENTARY SIGN WITH STOP LINE AND PAVEMENT LEGEND AFTER CONVERSION. (SAN BERNARDINO, CALIFORNIA)

FIGURE 25. SUPPLEMENTARY SIGN AFTER CONVERSION. (Note back-to-back signs on both posts.) (SAN BERNARDINO COUNTY, CALIFORNIA)

FIGURE 26. PAVEMENT MARKINGS AND "STOP AHEAD" SIGN USED TO EMPHASIZE PRESENCE OF REMAINING STOP SIGN AFTER CONVERSION. (SAN BERNARDINO COUNTY, CALIFORNIA)

NISKAYUNA

Niskayuna, New York uses its town board to act on matters relating to the installation and removal of traffic control devices. The town manager and highway engineer act in concert on matters affecting the town's traffic.

TROY

Troy, New York has a full-time traffic engineer devoted to traffic matters. The traffic engineer has been delegated the authority to install and remove stop signs and other traffic control devices. Interesting enough, in addition to traffic engineering studies identifying certain stop signs as unwarranted, the requirement for a supply of stop signs hastened the removal of unnecessary stop signs.

CONNECTICUT

MANCHESTER

The police department of Manchester, Connecticut has the authority to install and remove traffic control devices. After removal, an increase in accidents was noted at several intersections. One possible cause of the increase was the presence of stop lines on the approaches no longer required to stop. These stop lines might have indicated to those required to stop that opposing traffic was still required to stop. In fact after conversion, calls were received from those surprised by the conversion of the intersections.

Additionally, sight distance and grade problems are thought to have contributed to the increase in accidents. To combat the problems of speeding by motorists no longer required to stop, radar enforcement by police was employed.

Manchester agreed to participate in field testing of procedures developed by this research effort to safely remove multiway stop signs.

3.4 SUMMARY OF LOCAL EXPERIENCE

As the site visits indicate, many jurisdictions have converted multiway stop-signed intersections using a blend of engineering practice and local wisdom. While certain specific treatments may work better than others, the range of approaches is fascinating. Local traffic engineers with a sense of history and a feel for their unique political environment may wish to copy some of the approaches used by their counterparts throughout the country. Here is a summary of that local experience:

- Arrange public hearings and press coverage.
- Use supplementary warning signs up to 30 days before a conversion.
- Conduct detailed traffic studies including accident data, speed surveys, and environmental measurements.
- Develop a local warrant for multiway stops and conversions.
- Convert multiway stops during low activity periods such as the winter months.
- Remove the stop sign but leave the post in place for two weeks, then remove the post.
- Film the intersection to detect the type and frequency of stop sign violations.
- Convert multiway stops when your city annexes a subdivision.
- Send a notice of multiway conversions with the monthly water bills.
- Remember that sight distance becomes more critical when through street traffic no longer stops.
- Request increased law enforcement during the week following a conversion.
- Try replacing the 24" stop sign with a 30" stop sign until local motorists are aware of the conversion, then revert to the 24" sign.

- Advocate energy conservation as one benefit of multiway stop conversions.

- Always remove the stop line on the through street, an integral part of the conversion process.

Signing, of course, as depicted in this chapter, runs the gamut of human invention from cardboard stick-ons to oversized sheet metal. Some signs appear to have a greater impact on the motoring public.

4.0 ACCIDENT DATA ANALYSIS

One of the primary objectives of this study was to document the safety effects of converting multiway stop controls to two-way stop controls. This chapter reports on the results of the accident analysis to meet these objectives.

In addition to determining how accidents may change from the conversion, it was hoped to determine if certain conversion procedures might affect this change. For instance, if it could be established that certain procedures, including the use of special signs, could account for a drop in accidents or at least a smaller increase than that observed for sites without signs, then this finding could be used as a basis for recommending procedures to convert multiway stop sign control.

4.1 ACCIDENT DATA

Data were obtained for a total of 172 intersections representing 33 jurisdictions in 12 States. The primary data element was the number of accidents that occurred at the intersection both before and after the conversion. All accident types were included. For each study site, accident data were requested from the responsible jurisdiction for a period of one year before and one year after the conversion.

The data were received from the jurisdictions in a variety of formats which included either the police accident reports, a summary collision diagram, or a summary listing with very little information regarding individual accidents. In many instances, only an indication of the number of accidents that occurred was received.

In addition to the accident data, information was provided on the following:

- Population of the jurisdiction
- Posted speed
- Number of intersection legs, i.e., three-way or four-way
- The use of supplemental signs
- The total intersection volume
- The date of conversion

The data elements were not complete for all sites. This fact and the fact that the accident data was not consistent in its format, limited the type of analyses that could be performed.

4.2 ANALYSIS

The Statistical Program for Social Sciences (SPSS) computer package was used to analyze the data. The first analysis conducted was to determine if the conversion of multiway stop to two-way stop caused a change in accidents. Some summary statistics which provide an initial indication of the accident change are shown in Table 5.

TABLE 5. ACCIDENT SUMMARY STATISTICS

		Supplementary Sign	
	Total	Yes	No
Number of Accidents Before	88	77	11
Number of Accidents After	144	101	43
TOTAL (All Intersections)	232	178	54
Number of Intersections With Increased Accidents	28	13	15
Number of Intersections With Decreased Accidents	16	12	4
Number of Intersections With No Change	128	32	96
TOTAL	172	57	115

For all intersections combined there was a 64 percent increase (88 before, 144 after) in the total number of accidents after the conversion. When divided into those intersections with and without the use of supplementary signs, the increases were 31 percent and 291 percent, respectively. The first set of data indicates that:

a. There was a significant increase in the number of accidents (based on Poisson distribution test), and

b. the percentage increase in accidents was significantly higher where there were no supplementary signs (based on chi-square test).

However, aggregating the data for all intersections may be misleading; therefore, other analyses are appropriate to provide a more complete picture.

Other data in Table 5 show the number of intersections that increased, decreased, or had no change in accidents with the conversion. Again, the data are divided into sites with or without supplemental signs.

This data indicates that 74 percent of the intersections (128 of 172) had no change in the number of accidents. For all of these no-change locations it was reported that there were no accidents in the two-year study period. Of those that showed a change, 28 intersections increased in accidents and 16 intersections decreased in accidents.

When the data are divided into sites with and without supplementary signs it is observed that there were a nearly equal number of intersections increasing and decreasing in accidents where signs were used. But where there were no signs, the number of intersections increasing in accidents were nearly four times the number decreasing. (A chi-square analysis revealed that the distributions of accidents between signs and no-signs were significantly different). However, the data also revealed that a higher percentage of intersections with supplemental signs experienced an increase in accidents than did intersections without supplemental signs.

The results stated above provide a different assessment of the safety affects of the conversion. Although the aggregate affect was a significant increase in accidents, only 16 percent of the 172 sites experienced an increase and 9 percent experienced a decrease. This finding indicates that there might be certain geometric or operating characteristics which determine whether or not an increase in accidents will occur.

With regard to the influence of signs it is difficult to draw a conclusion. Where signs were used, there was a significantly higher percentage of intersections both increasing and decreasing in accidents than for sites where signs were not used. This could be interpreted that signs can have a beneficial or deleterious effect depending on the specific situation. Another indication of the opposite effects on accidents associated with the use of signs is seen in Figure 27, which shows a frequency bar chart of the number of intersections with the change in accidents. At the tails of the distribution it is observed that intersections with signs experienced the highest increase in accidents and the highest decrease in accidents.

As noted before, it appeared that the increase or decrease in accidents resulting from the conversion might be influenced by certain other factors other than the use of supplemental signs. To determine this, a multiple regression analysis was performed using both the absolute and percent change in accidents as the dependent variable and the following independent variables for which data were collected:

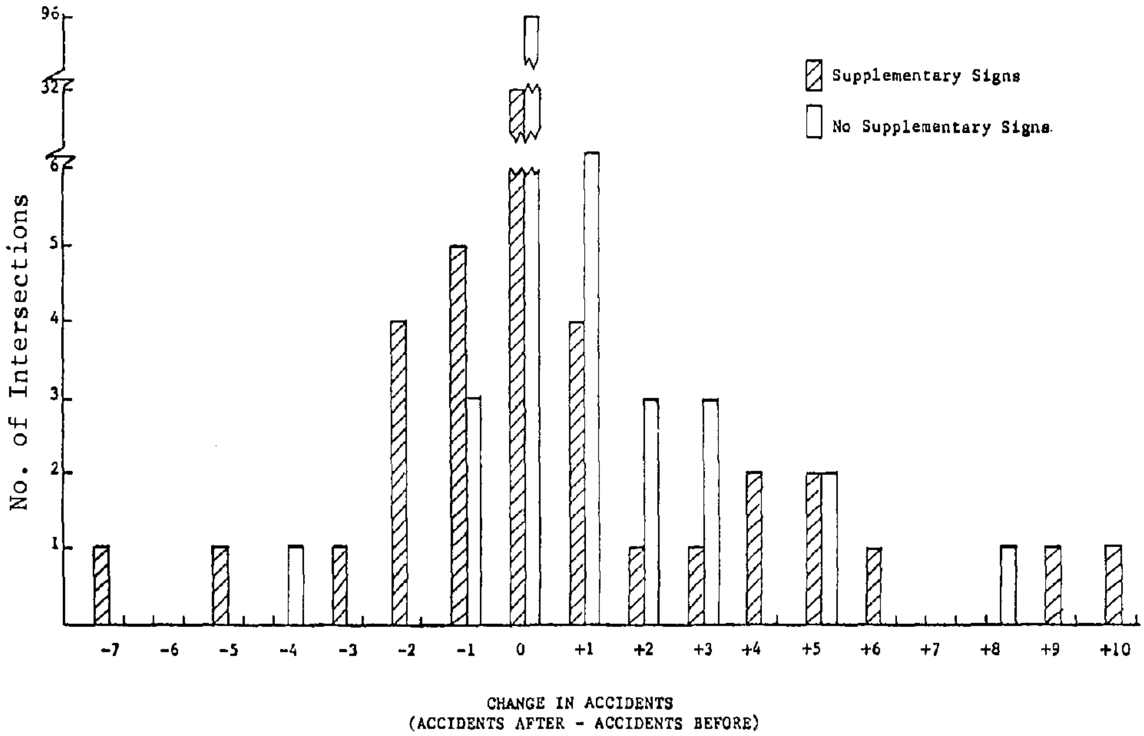

FIGURE 27. FREQUENCY OF INTERSECTIONS WITH CHANGES IN ACCIDENTS WITH AND WITHOUT SUPPLEMENTARY SIGNS

- Posted speed (equal speeds assumed for both approaches)
- Total intersection volume
- Population of jurisdiction

This analysis revealed no significant relationships.

The final accident analysis performed was to determine, at those sites where the accidents increased, how soon the accidents occurred after the conversion took place. One would expect that there might be an unusually high incidence of accidents immediately after the conversion with a returning back to a "normal" situation after the motorist had become fully aware that the intersection was a two-way stop control.

The results of this analysis are illustrated by Figure 28. It shows the number of accidents that occurred for each of 12 months before and after the conversion for 5 sites combined. These were the only sites that experienced an increase in accidents and for which it was known when the accidents and when the conversion took place.

Although the sample size is fairly small to make a conclusive statement, it appears that if accidents do increase, there is a concentration of accidents occurring within the first month. The remainder of the accidents occurred throughout the balance of the year with the fluctuations expected of normal accident occurrence.

4.3 SUMMARY AND CONCLUSIONS

The accident analysis was only partially successful in achieving the intended objective. With regard to the issue of whether or not accident frequency changes as a result of the conversion, no generalized conclusions can be drawn. It is certain that for some intersections, accidents will increase and as a direct result of the conversion. In aggregate there was a significantly higher number of accidents and more intersections increased in accidents than decreased. No positive relationships could be determined between any operational or geometric factors and accident change. However, it is noted that at none of the locations which experienced a high increase in accidents were there low volumes (less than 1,500 ADT total intersection).

There is an evidence that the first month immediately after the conversion is the most critical period for accident increase. Motorist who had traveled through the intersection frequently when under a multiway control, expect the opposing traffic to stop. Even after the conversion, this expectation can linger on as is evident from the time line analysis. Anecdotal information supporting this phenomenon is seen from the narrative Statements excerpted from the police report for two accidents:

> "Vehicle No. 1 stated he stopped for stop sign and then proceeded forward believing Vehicle No. 2 had a stop sign because of the white stop lines still painted on Park Street." (Note: Park Street previously had a stop sign which was removed.)

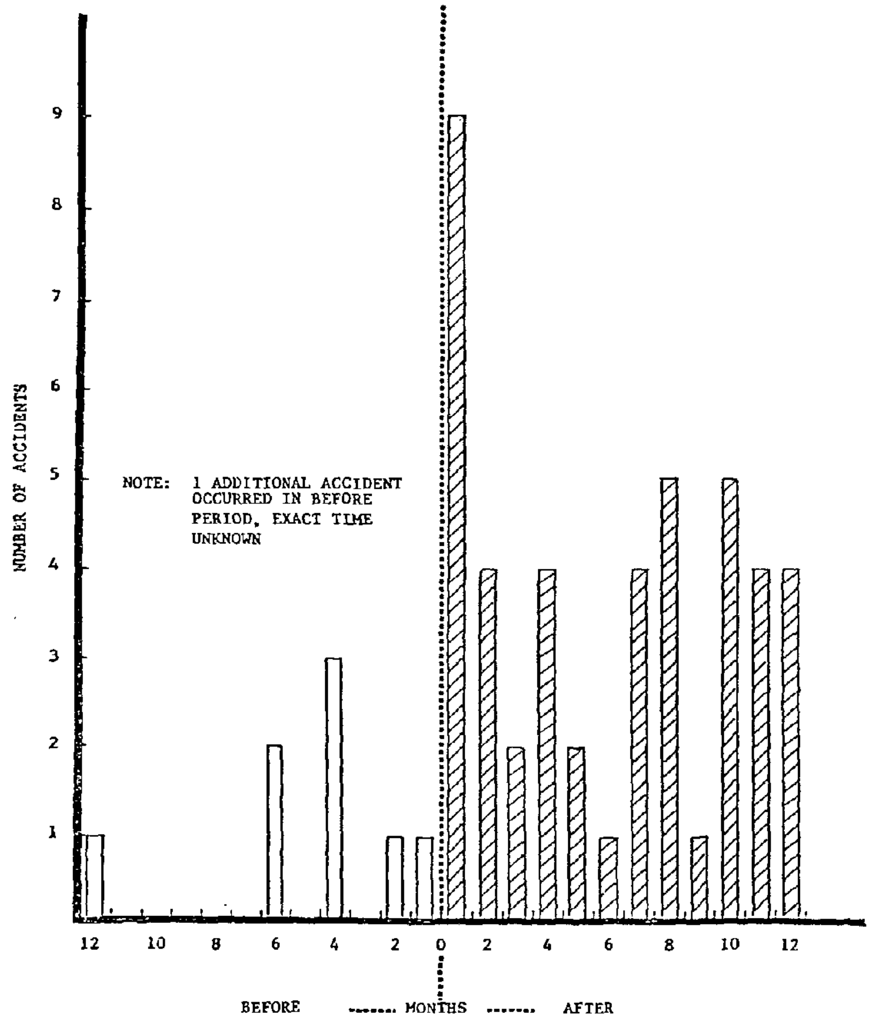

FIGURE 28. TIME TREND OF ACCIDENT OCCURRENCE BEFORE AND AFTER CONVERSION

"...Operator No. 1 also Stated she still believed the intersection was a four-way stop and she expected Vehicle No. 2 to stop." (Note: Approach for Vehicle No. 2 was previously controlled by a stop sign but was removed.)

The use of supplemental signs are intended to overcome this expectation. By advising motorists in the future that the conversion will take place at a certain time, and/or, after the conversion has taken place, warning motorists on the stop-controlled approaches that the other approaches do not require a stop, it is hoped that motorists will quickly adapt to the new system.

In regard to the effect of supplementary signs, the results of the analysis were conflicting. On the one hand, where signs were used, there was a greater percentage of sites where accidents decreased, and, overall, there was a smaller percentage increase in accidents compared to sites without signs. However, what cannot be ascertained is what further increase in accidents might have occurred if the signs were not used.

5.0 EVALUATION OF SUPPLEMENTARY SIGNS

5.1 SELECTION OF CANDIDATE SUPPLEMENTARY SIGNS

In order to test warning/information signs and advance notice signs, several alternative warning signs were considered. Based on the data collected in the field from almost 200 intersections where multiway stop signs had been removed, on suggestions by State, county, and municipal agencies, on reviews of the literature, and on discussions with members of the research team, seven different sign messages were formulated. These are shown in Appendix C, using a hypothetical Green Street-Elm Street intersection. This example was tested with about 30 participants at the University of Maryland. As a result of this preliminary preference test, a total of four signs were fabricated by the Baltimore Department of Transit and Traffic. Once these were fabricated, slides of these signs, together with slides taken at actual field locations formed the basis for a laboratory experiment to test both the meaning and the motorist's preference from among eleven sign message alternatives (see Table 6 and Figure 29).

TABLE 6. MESSAGES OF SIGNS USED IN LABORATORY EVALUATION

1.	Two-Way
2.	Two-Way; Caution; Cross Traffic Does Not Stop
3.	Two-Way; Caution; Watch For Thru Traffic
4.	Two-Way; Caution; Watch For Cross Traffic
5.	Two-Way; Caution; No Longer Four-Way Stop
6.	Caution; Cross Traffic Does Not Stop
7.	Caution; Watch for Thru Traffic
8.	Caution; Watch for Cross Traffic
9.	Caution; No Longer Four-Way Stop
10.	Caution; No Longer Four-Way
11.	No Stop On Cross Street

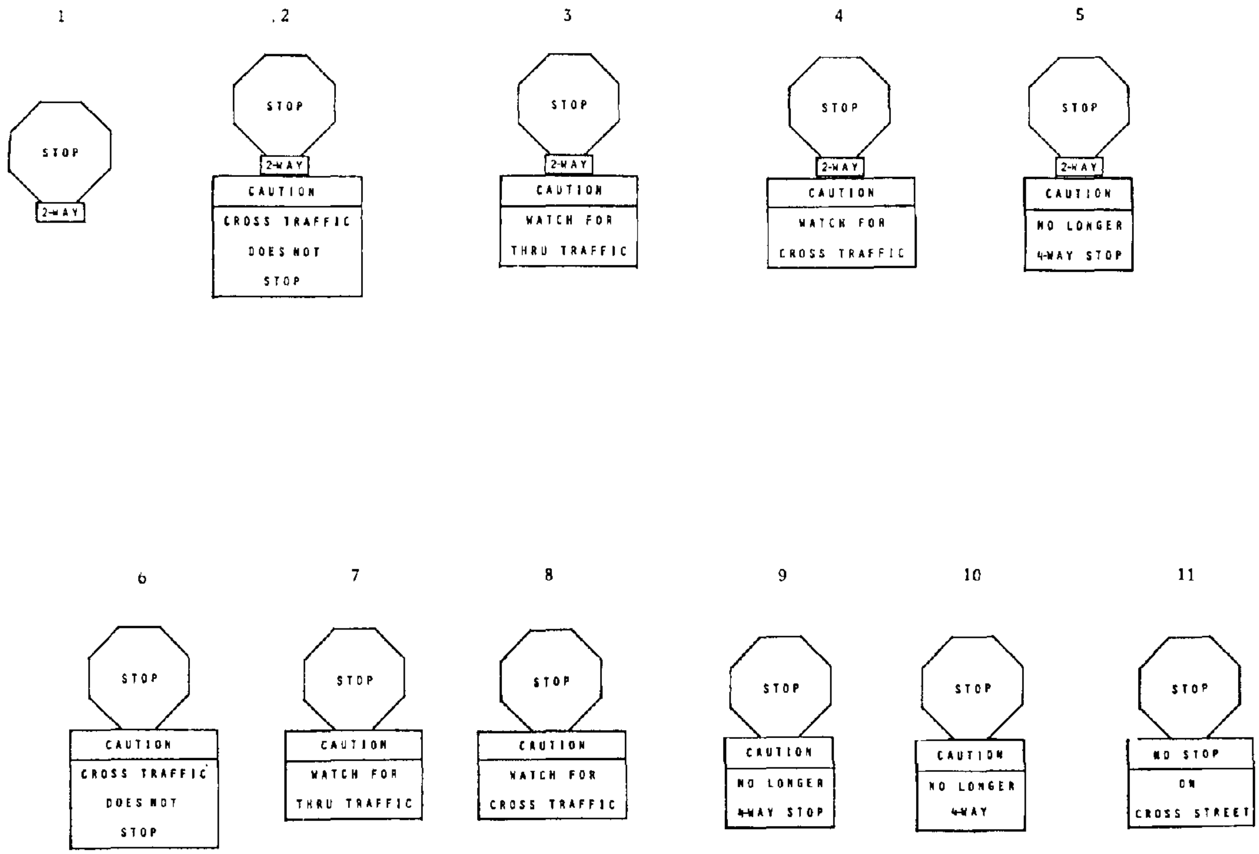

FIGURE 29. SIGN MESSAGES SELECTED FOR LABORATORY TEST EVALUATION

Slides of these eleven signs were then used in laboratory tests, beginning with a draft personal data questionnaire and test procedure at the Federal Highway Administration, Turner-Fairbank Highway Research Center. The questions, format, and testing procedure, including developing new and better slides of the candidate signs, were revised and the laboratory tests were administered to the groups indicated in Table 7.

TABLE 7. SUMMARY OF LABORATORY TEST OF CANDIDATE SIGNS

Site	Sign Sequences No.*	Question Sets **	No. of Subjects
FHWA	1	6 different sets	38
U.S. Army Reserves	2	2 different sets	25
	3	2 " "	20
	4	2 " "	3
MD. State Police Academy	5	2 different sets	37
University of Maryland Senior Class	6	2 different sets	30
University of Maryland Health Class	7	4 different sets	75
TOTAL	7	20	228

* See Appendix D for the randomized order of presentation of candidate signs.

** A total of 53 multiple choice questions (A through D answers, with one best and at least one correct answer) were developed. These were randomly assembled into 20 different sets of 11 questions each. Appendix E presents a typical set.

5.2 LABORATORY TESTING OF SUPPLEMENTARY SIGNS

The laboratory testing was accomplished for each group by first briefly describing the general problem of excess stop sign control at intersections. Then the test began by showing a slide of a typical four-way stop-controlled intersection indicating that the control has been changed and then showing a slide of the first sign in the eleven-sign sequence (at the same intersection) and asking the participants to answer a, b, c, or d. This continues until slides of all eleven signs have been shown.

Next the subjects are asked to rate the advance (about one month prior to conversion) signs on the street with stop control remaining and on the street where stop signs are to be removed. The last part of the test is the comparative ranking of the top three of the eleven signs as first, second, or third choice. Finally, the subjects are given the opportunity to provide comments and suggestions.

Prior to beginning the laboratory sign evaluation test, each subject was requested to complete a five question (checkoff) classification questionnaire (first page of the packet provided). Pages 2 through 7 contain the eleven sets of questions for Part I of the evaluation. Page 8 was the rating page for the two notice signs (30 days in advance of removal). Page 9 is the comparative evaluation of the eleven signs and page 10 is a figure depicting the eleven signs. A typical packet is shown in Appendix E.

The actual laboratory experiment was developed in two parts. Part I tested sign meaning and consisted of slides of a four-way stop intersection (Before) and the same intersection as a two-way stop (After), followed by slides of each of the alternative sign messages for warning/information. A series of four answers were developed for testing the subject on sign message meaning for each sign. For example, the answers might be:

(a) I no longer have to stop.

(b) I don't know which approaches have to stop, but I do have to stop.

(c) Traffic approaching from the left and the right is not required to stop, and I am

(d) Not certain.

The order in which the signs were presented was randomized in order to reduce any learning bias. Also, the 11 out of 53 possible question sets were chosen at random.

A total of 102-female and 123-male subjects participated in the testing. The subjects ranged from 16 to 64 years of age and their driving frequency ranged from everyday to one time per week. The subjects were reasonably representative of a range of ages except there were few females over 40 years of age.

5.3 SIGN INTERPRETATION AND PREFERENCE

Table 8 shows drivers understanding of the seven basic supplementary sign messages. The "CROSS TRAFFIC DOES NOT STOP" sign was clearly the best understood. There was no difference between male and female subjects in the percentage of correct responses.

Two types of incorrect responses were possible. One misinterpretation was that the driver no longer had to stop or yield to cross street traffic. This interpretation would be unsafe and was the most common incorrect response to the two "WATCH" signs as shown in Table 9. The other incorrect response was that the driver was not sure what the sign meant. This was the most common incorrect interpretation of the two-way placard and the three "NO" messages.

Table 10 gives the drivers ranking of the signs used to warn/inform of the change from all-way stop to stop on the minor road. The results shown are almost identical with a preliminary analysis of the first 90 subjects. The "CROSS TRAFFIC DOES NOT STOP" sign was again the most preferred message followed by "NO LONGER FOUR-WAY STOP."

The preference for signs that might be used in advance (i.e., as advance warning) of the intersection are indicated in Table 11. Only the top five choices are shown. Thus, for advance warning signs, the preference was also for "NO LONGER FOUR-WAY STOP" and "CROSS TRAFFIC DOES NOT STOP," and the same two signs with a two-way placard.

Two signs intended to notify motorists of the conversion about 30-days before the stop signs are actually removed were rated on a 5-point scale ranging from excellent to poor. The advance notification sign on the street which is to retain stop control has a message, "NOTICE, CROSS TRAFFIC WILL NOT STOP EFFECTIVE (day and date)." The advance notification sign for the street which will have stop signs removed has a message, "NOTICE, THIS SIGN WILL BE REMOVED EFFECTIVE (day and date)."

Including the subjects in the first laboratory test at Turner-Fairbank Highway Research Center (when the procedures and slides were still being modified), the two advance notification signs received a good to very good rating as shown in Table 12.

5.4 SUMMARY

In summary, the sign evaluation laboratory tests results were consistent with the field experience found during field visits and by literature review as well as correspondence with State, county, amd municipal officials. This also agrees with the engineering judgement of the research team. The black "CAUTION" on yellow background separated from the black maessage on white background "CROSS TRAFFIC DOES NOT STOP" is a top candidate as a supplementary sign for safe removal of multiway stop signs. The same top portion "CAUTION" with the bottom message, "NO LONGER FOUR-WAY STOP," is a close second on preference.

TABLE 8. CORRECT RESPONSES TO 7 BASIC SUPPLEMENTARY SIGNS

Sign	Percent Correct
TWO-WAY	89.2
NO LONGER FOUR-WAY STOP	89.1
CROSS TRAFFIC DOES NOT STOP	96.1
WATCH FOR CROSS TRAFFIC	91.2
WATCH FOR THRU TRAFFIC	91.9
NO LONGER FOUR-WAY	87.6
NO STOP ON CROSS STREET	90.0

TABLE 9. INCORRECT RESPONSES TO 7 BASIC SUPPLEMENTARY SIGNS

Sign	Percent Incorrect	
	No Stop Required Other Traffic Yields	Not Certain
TWO-WAY	5.4	5.4
NO LONGER FOUR-WAY STOP	4.7	6.2
CROSS TRAFFIC DOES NOT STOP	1.4	2.5
WATCH FOR CROSS TRAFFIC	5.0	3.8
WATCH FOR THRU TRAFFIC	4.3	3.8
NO LONGER FOUR-WAY	2.8	9.6
NO STOP ON CROSS STREET	2.8	7.2

TABLE 10. SIGN PREFERENCE FROM THE LABORATORY COMPARATIVE ANALYSIS

SIGN NO.	CHOICE FIRST	CHOICE SECOND	CHOICE THIRD	WEIGHTED PREFERENCE* WEIGHT	WEIGHTED PREFERENCE* RANK
1	30	9	15	123	4
2	66	40	15	293	1
3	10	11	17	69	9
4	14	19	29	109	6
5	28	27	16	154	3
6	34	41	28	222	2
7	13	6	12	57	10
8	11	18	17	86	7
9	14	22	26	112	5
10	4	12	9	45	11
11	4	19	20	70	8
TOTAL	228	224	204		

* 1st Choice 3, 2nd Choice 2, 3rd Choice 1

TABLE 11. PREFERENCE FOR SIGNS IN ADVANCE OF THE INTERSECTION

SIGN NO.	CHOICE FIRST	CHOICE SECOND	CHOICE THIRD	WEIGHTED PREFERENCE* WEIGHT	WEIGHTED PREFERENCE* RANK
9	38	27	9	177	1
6	28	30	12	156	2
5	26	13	21	125	3
2	25	18	7	118	4
8	12	15	9	75	5

*1st Choice 3, 2nd Choice 2, 3rd Choice 1

TABLE 12. LABORATORY RATING OF ADVANCE NOTIFICATION SIGNS

	E	VG	G	P	VP	Total	Weighted Rating*
Sign on Street with stop control remaining	30	62	101	32	9	234	3.3
Sign on Street with stop control removed	33	72	91	25	12	233	3.4

* Excellent 5; Very Good 4; Good 3; Poor 2; Very Poor 1.

6.0 RECOMMENDED CONVERSION PROCEDURES (RCP)

6.1 GENERAL

These recommended procedures are the result of empirical data collected from more than 30 political jurisdictions throughout the country. Often, practices by these cities and towns varied widely in the manner by which they removed unwarranted stop signs. However, there appeared to be a consensus among the various officials interviewed on the necessary actions to safely convert an intersection from a multiway stop condition to a lesser form of control.

The recommended procedures in the following section were developed based largely on the experiences of these practicing traffic and law officials, laboratory experiments with supplementary signs, and results of field testing of these procedures. Detailed procedures are found in Volume II of this report. Aside from recommended signs developed as a result of this research effort, all other signs and markings used should be in accordance with the manual on Uniform Traffic Control Devices.

6.2 CONVERSION PROCEDURES (ABBREVIATED)

Pre-Conversion Phase

1. Conduct traffic engineering studies as appropriate to determine if stop signs are warranted.

2. Secure necessary approval for removing unwarranted stop signs.

3. Publicize impending conversion.

4. Post "NOTICE" signs beneath stop signs (30-days prior to conversion) on respective approaches. (See Figures 30 and 31.)

Conversion Phase

1. Remove unwarranted stop signs (prior to beginning of a.m. peak period on day of conversion).

2. Remove all "NOTICE" signs.

3. Post "CAUTION" sign(s) beneath remaining stop sign(s) after removing four-way supplementary plates, if installed. (See Figure 32.)

4. Remove and/or install "STOP AHEAD SIGN(s)" (W3-1W3-1A) as appropriate.

5. Add pavement markings as necessary.

6. Remove obsolete pavement markings.

7. Improve sight distance.

   a. Restrict parking.
   b. Prune vegetation.
   c. Other.

Post Conversion Phase

1. Traffic engineering monitoring (as appropriate).

   a. Volume changes.
   b. Motorists' compliance.
   c. Speed Changes.
   d. Driver behavior/conflict.
   e. Accidents.

2. Police Enforcement (Prior coordination required).

3. "CAUTION" sign(s) removed (90 days after conversion).

FIGURE 30. NOTICE SIGN TO BE POSTED BENEATH STOP SIGN TO BE REMOVED

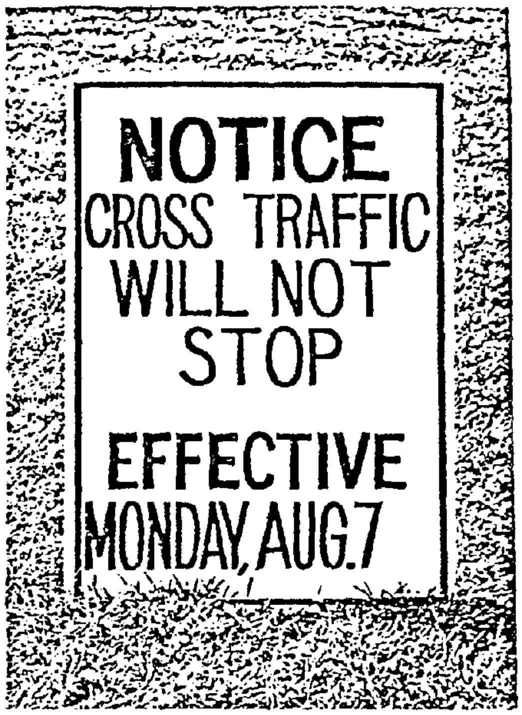

FIGURE 31. NOTICE SIGN TO BE POSTED BENEATH STOP SIGN WHICH IS TO REMAIN

SPECIFICATIONS (Both Signs)

1. Overall Sign Dimensions - 18" x 24"
2. Lettering Size - Top and Bottom Lines - 3"
   All Others - 2½"
3. Color - Black Letters on White Background
4. Surface - Reflective Sheeting

1. Overall Sign Dimensions - 18" x 24"
2. Yellow Band Dimensions - 6" x 24"
3. Lettering Height - 4"
4. Colors - Black Letters on Yellow and White Backgrounds
5. Surface - Reflective Sheeting

FIGURE 32. CAUTION SIGN TO BE POSTED BENEATH REMAINING STOP SIGN(S) ON THE DAY OF CONVERSION

7.0 FIELD TESTS OF CONVERSION PROCEDURES

7.1 GENERAL

Once preliminary conversion procedures had been developed, it remained to have them field tested by local jurisdictions volunteering to do so. Given that a change in traffic control at an intersection normally requires legislative action by local authorities, and given the lead time required for this action, only certain jurisdictions were in a position to participate in stop sign removals within the time frame imposed by the project duration.

Two such municipalities which were visited as a part of the data collection phase consented to participate in the field testing of conversion procedures developed by the research team. They were Manchester, Connecticut and Kansas City, Missouri.

No attempt is made to compare motorists' behavior after conversion at the two locations largely because of the judgemental data collected by four different observers at those locations.

7.2 MANCHESTER, CONNECTICUT

Manchester, Connecticut is a town with a population of approximately 52,000 situated adjacent to East Hartford, Connecticut. Traffic matters are handled by the Manchester Police Department. Manchester had experienced a number of accidents at converted intersections in the past. Poor sight distances and the continued presence of the stop line on approaches no longer required to stop, were cited as contributing factors to the accident rate. Additionally, Manchester did not employ "Notice" or "Caution" signs as a part of its programs to inform the motoring public of pending or actual conversions. A site diagram for the intersection converted by Manchester is shown in Figure 33.

The intersection chosen by the town of Manchester for conversion as a part of this research effort was Summit and Hollister Streets. Summit is a north-south residential collector intersecting Hollister, an east-west local residential street. Total intersection ADT is approximately 1700 vehicles per day with 88 percent of the volume on Summit. Detached single family homes are situated on three corners with a training center for retarded citizens on the fourth corner. The intersection has been under four-way stop control since 1971. Posted speeds in the area are 30 mph. Figure 34 is the intersection looking north on Summit. Figure 35 is the intersection looking east on Hollister.

On September 19, 1983, the notice signs in Figures 36 and 37 were posted beneath the stop signs at the intersection of Summit and Hollister Streets.

These notice signs remained in place for approximately 30 days to alert the motoring public concerning the impending change. In addition, three local newspapers were notified of the stop sign removal program in general and the proposed conversion of the intersection of Summit and Hollister Streets in particular.

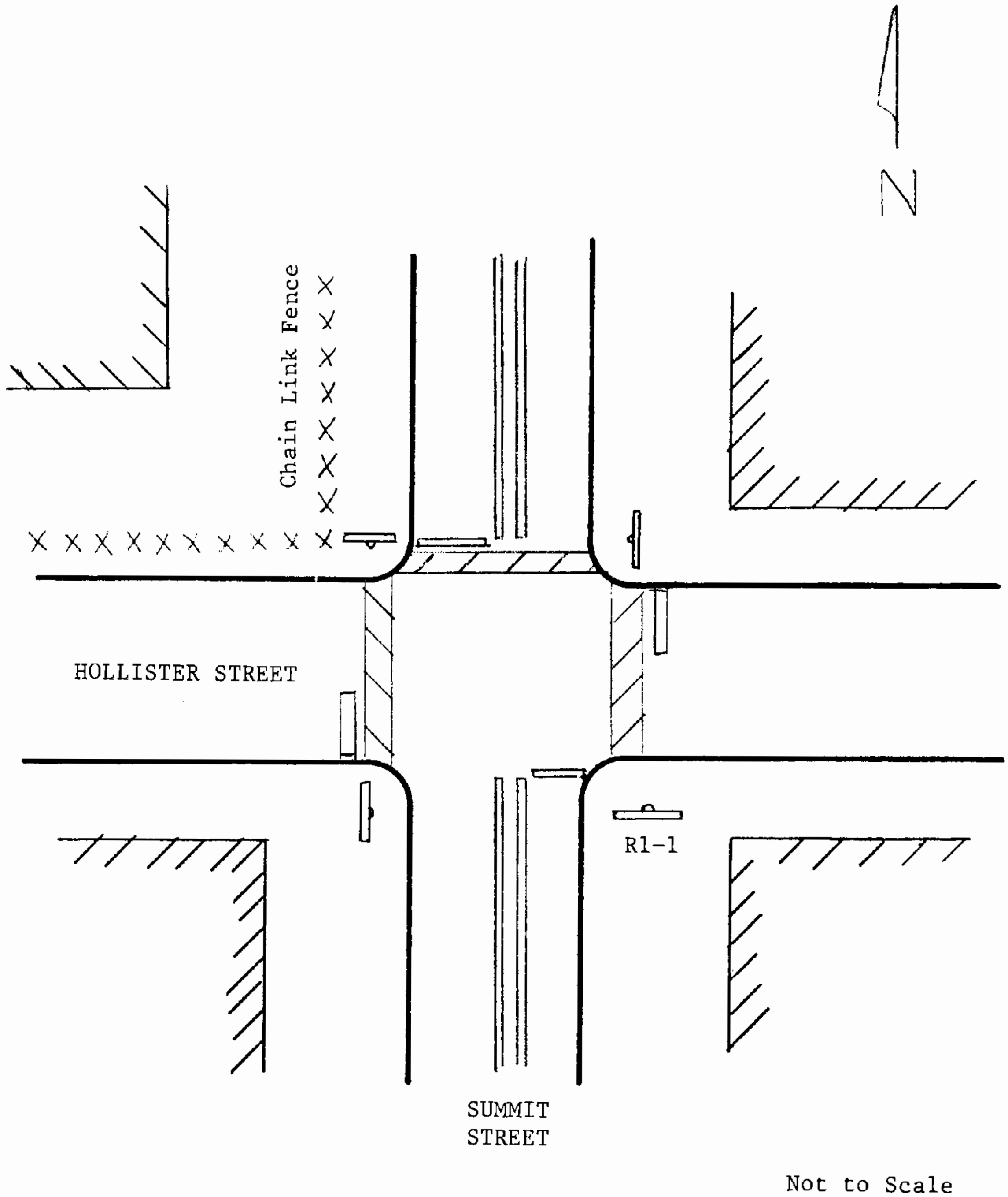

FIGURE 33. SITE DIAGRAM. SUMMIT AND HOLLISTER STREETS.
(MANCHESTER, CONNECTICUT. October 16, 1983)

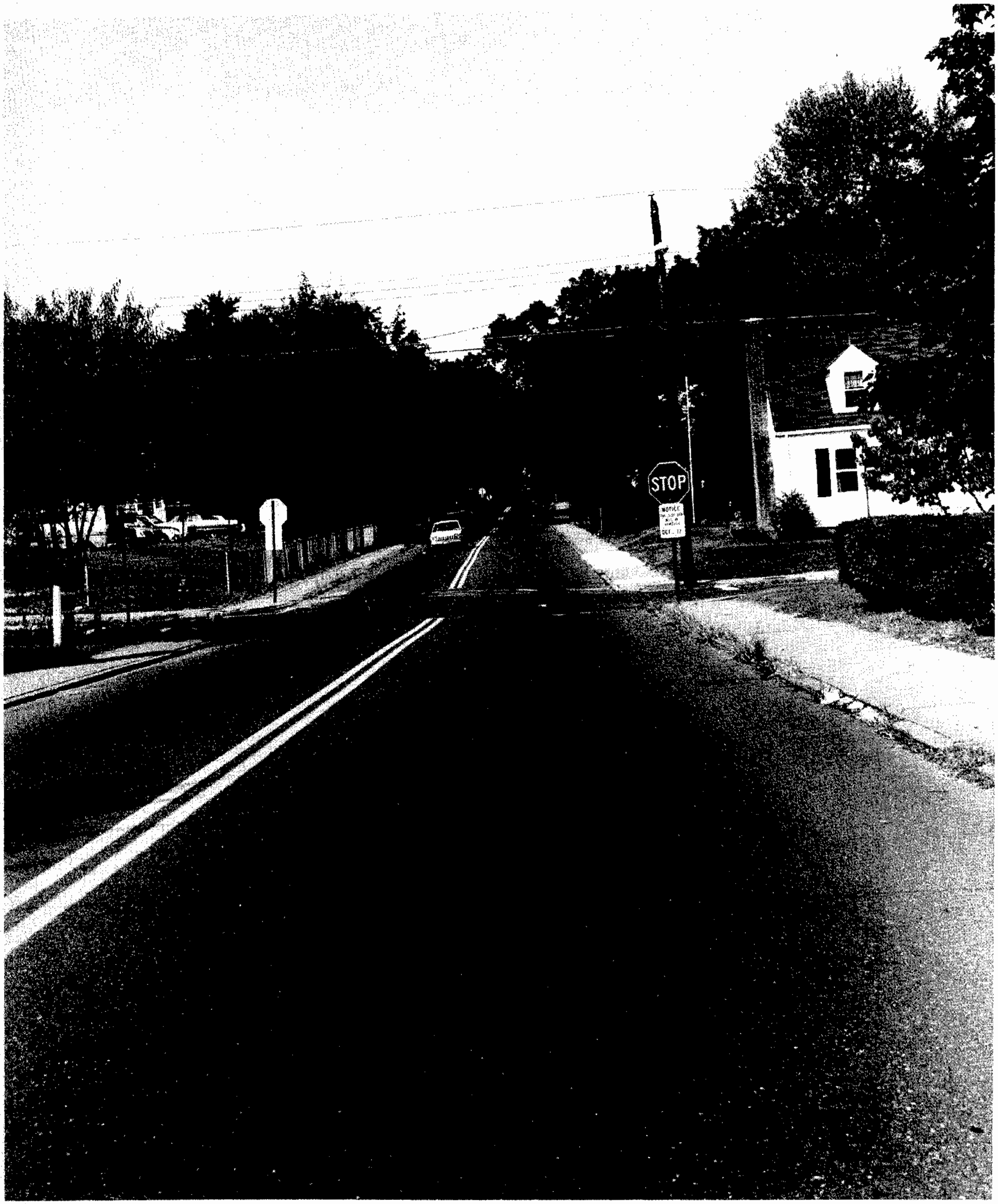

FIGURE 34. NORTHBOUND ON SUMMIT. (MANCHESTER, CONNECTICUT)

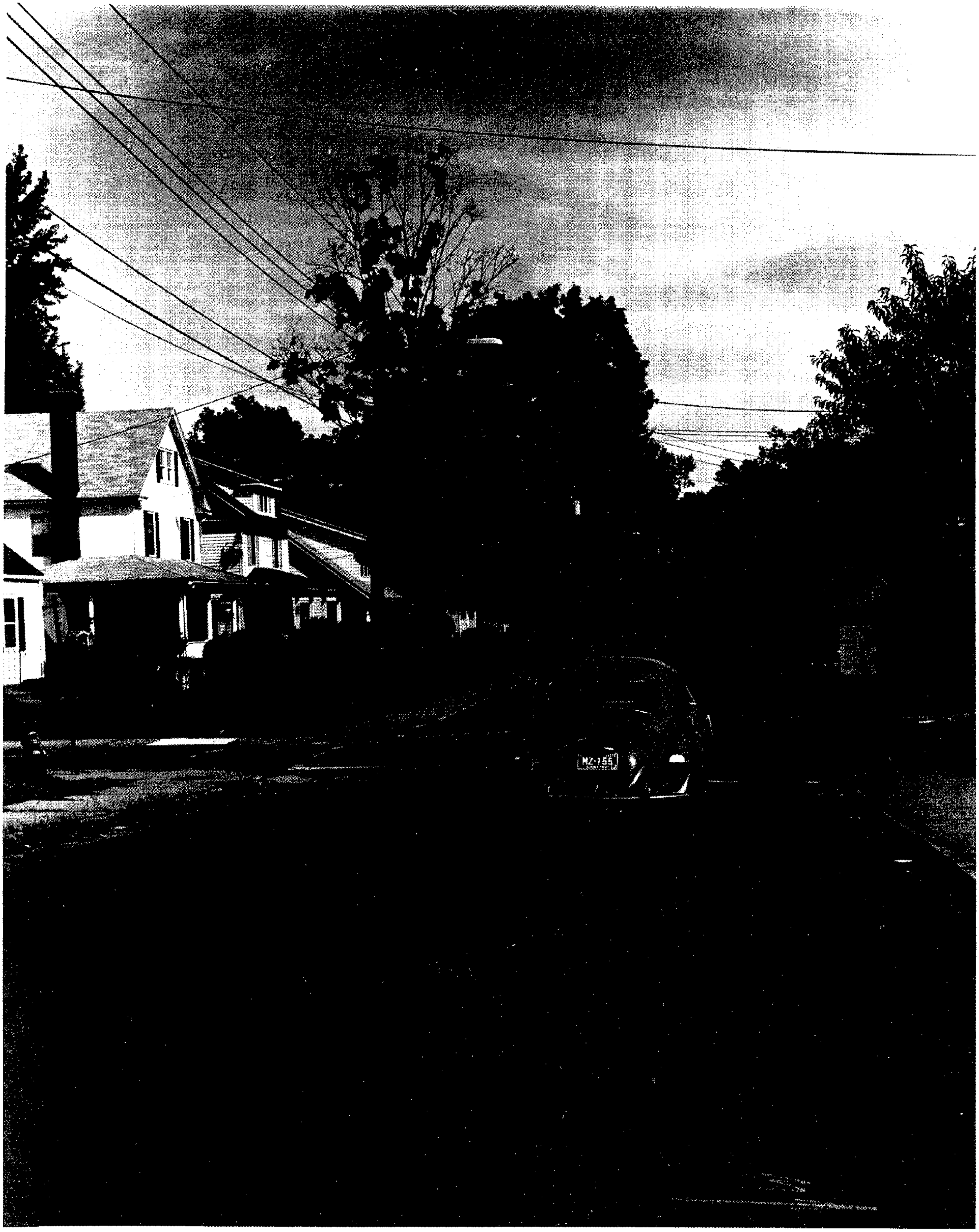

FIGURE 35. EASTBOUND ON HOLLISTER. (MANCHESTER, CONNECTICUT)

FIGURE 36. NOTICE SIGN BENEATH STOP SIGNS ON SUMMIT STREET PRIOR TO CONVERSION. (MANCHESTER, CONNECTICUT)

FIGURE 37. NOTICE SIGN BENEATH STOP SIGN ON HOLLISTER STREET PRIOR TO CONVERSION. (MANCHESTER, CONNECTICUT)

To improve sight distance at this intersection, one resident was asked in writing by the town's zoning enforcement officer to prune the lower branches of a shrub on the southwest corner of Summit and Hollister. This was done.

The traffic division of the Manchester Police Department received one letter of protest from the principal of a school which was situated near the intersection to be converted. His concern was for the safety of 17 youngsters who boarded the school bus at that intersection. The Manchester Police Department which also coordinates school bus matters, arranged to have 12 of the 17 students picked up at another intersection prior to the conversion taking place. At 6:00 a.m. on Monday, October 17, 1983, the two stop signs on Summit Street were removed. The notice signs beneath the remaining stop signs on Hollister were replaced by the caution sign in Figure 38. The principal investigator and the FHWA contracting officer's technical representative were on hand to observe the actual conversion.

Traffic counts were taken during the morning period, 6:30 a.m. - 8:30 a.m., and the evening peak period, 3:00 p.m. - 5:00 p.m., on the day of conversion. The results of these counts are shown in Tables 13 and 14.

Observations at the site on the day of conversion revealed that motorists not yielding properly on Hollister Street (still required to stop) were often local residents. This was determined, where sight distance permitted, by observing where a motorist had originated or terminated his trip.

The notice signs used at the site (Figures 36 and 37) appeared to have been effective in notifying the motoring public of the impending conversion. Often motorists on Hollister not yielding properly would use facial or hand expressions which indicated they were aware of the changed intersection conditions but simply forgot.

It was observed that one motorist hesitating on the approach no longer required to stop will influence others on both approaches of the same street. The existence of a crosswalk on the southbound approach of Summit Street caused traffic to hesitate or stop when a pedestrian appeared at the curb. This made it difficult, if not impossible, to determine if the motorist stopped or hesitated due to habit or to yield to the pedestrian.

Observations during the 30-day period after conversion by the Manchester Police Department revealed peak hour traffic counts of 125 v.p.h. for Summit Street and 25 v.p.h. for Hollister Street. The area was also surveyed for speed during the peak hours and off-peak hours, and an 85 percentile of 38 m.p.h. for Summit Street in the area of the intersection was obtained.

Three accidents occurred during this 30-day period. Two of the accidents involved drivers who are residents of Hollister Street. The persons involved in one of the accidents have petitioned the neighborhood for replacement of the stop signs but no other negative activity has taken place with regard to their removal.

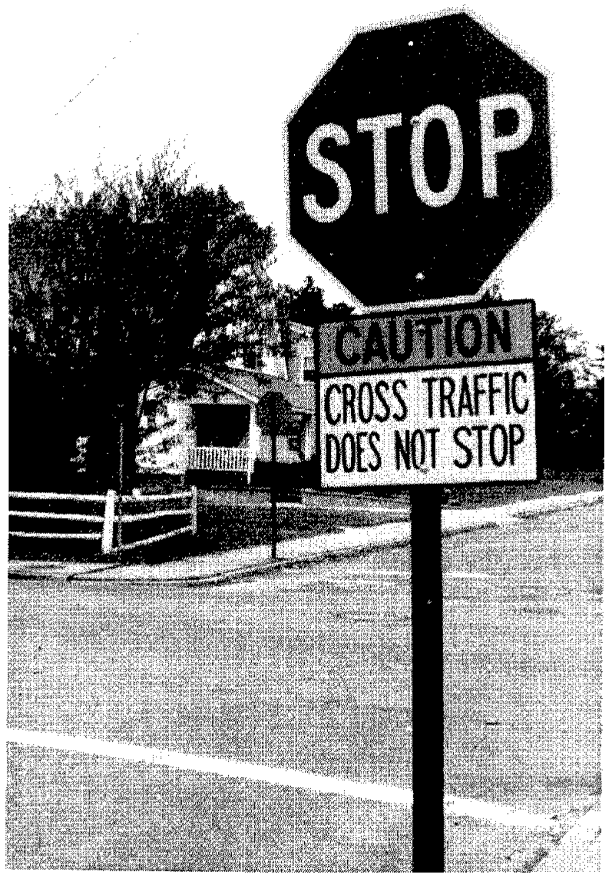

FIGURE 38. CAUTION SIGN BENEATH STOP SIGNS REMAINING ON HOLLISTER STREET AFTER CONVERSION. (MANCHESTER, CONNECTICUT)

TABLE 13. PEAK HOUR COUNTS ON SUMMIT STREET AFTER CONVERSION

SUMMIT STREET (NB & SB)*

Time/Date	Nonstop	Stop/hesitated	Total	% Stopping or Hesitating
6:30 - 8:30 a.m. 10/17/83	523	104	627	16.6
3:00 - 5:00 p.m. 10/17/83	920	123	1043	11.8

* Stop signs removed on this street.

TABLE 14. PEAK HOUR COUNTS ON HOLLISTER STREET AFTER CONVERSION

HOLLISTER STREET

Time/Date	Traffic Direction	Stopped (% Total)	Running Stop	Non Stop	Causing Near Miss	Total
6:30 - 8:30 a.m. 10/17/83	WB EB	56 (80.0%) 20 (86.9%)	2 1	0 0	12 2	70 23
3:00 -5:00 p.m. 10/17/83	WB EB	44 (91.7%) 121 (93.8%)	1 3	0 0	3 5	48 129

7.3 KANSAS CITY, MISSOURI

In 1982, the Traffic Control Division of the Kansas City Transportation Department undertook a program to eliminate unnecessary "Stop" signs at intersections where the volume of vehicular and pedestrian traffic is small. They theorized that the elimination of these unwarranted signs reduce delays, save fuel and improve the attitude of motorists toward traffic control devices in general.

Traffic engineering studies were conducted by Kansas City at 19 intersections controlled by four-way stop signs. Data obtained included date of count, count period, traffic volume on major and minor streets and direction of travel. Field investigations were also made to study the geometrics and visibility at these intersections. Of the 19 intersections studied, 15 were found not to meet the MUTCD criteria for four-way stop control. One of these, 79th Street and Ward Parkway Plaza, was selected as a site for field testing the recommended conversion procedures developed by this current research study.

79th Street and Ward Parkway Plaza is the intersection of a residential collector with a local street. Traffic counts at this intersection were conducted on September 14, 1983 as a part of the stop sign removal process (see Figure 11). A site diagram is shown in Figure 39. On October 3, 1983, the notice signs in Figures 40 and 41 were posted beneath the stop signs at the intersection of 79th Street and Ward Parkway Plaza. These notice signs remained in place until November 1, 1983, the day of conversion. In addition to this notice to the motorists at the intersection proper, letters were sent to households in the immediate neighborhood.

At 9:00 a.m. on Tuesday, November 1, 1983, the stop signs on 79th Street were removed along with the associated "STOP AHEAD" signs. The notice signs beneath the remaining stop signs on Ward Parkway Plaza were replaced by the "CAUTION" sign in Figures 42 and 43. The principal investigator was on hand to observe the actual conversion.

Traffic counts were taken during the evening peak period, 4:00 p.m. - 6:00 p.m. on November 1, 1983 and during the morning peak period, 7:00 a.m. - 9:00 a.m., November 2, 1983. The results of these counts are shown in Tables 15 and 16.

Observations on the day of conversion indicated that during the morning peak, prior to the stop signs being removed on 79th Street, some motorists were either not stopping or simply slowing for the stop signs. This was interpreted to mean that these motorists were aware that the stop signs were to have been removed on that day. It is important, therefore, to convert the intersections prior to the morning peak period.

The weather on the day of conversion was overcast with periods of rain. In spite of this condition, and the darkness during the evening peak hours, no accidents occurred at the site. Good sight distance on both approaches contributed to this phenomenon.

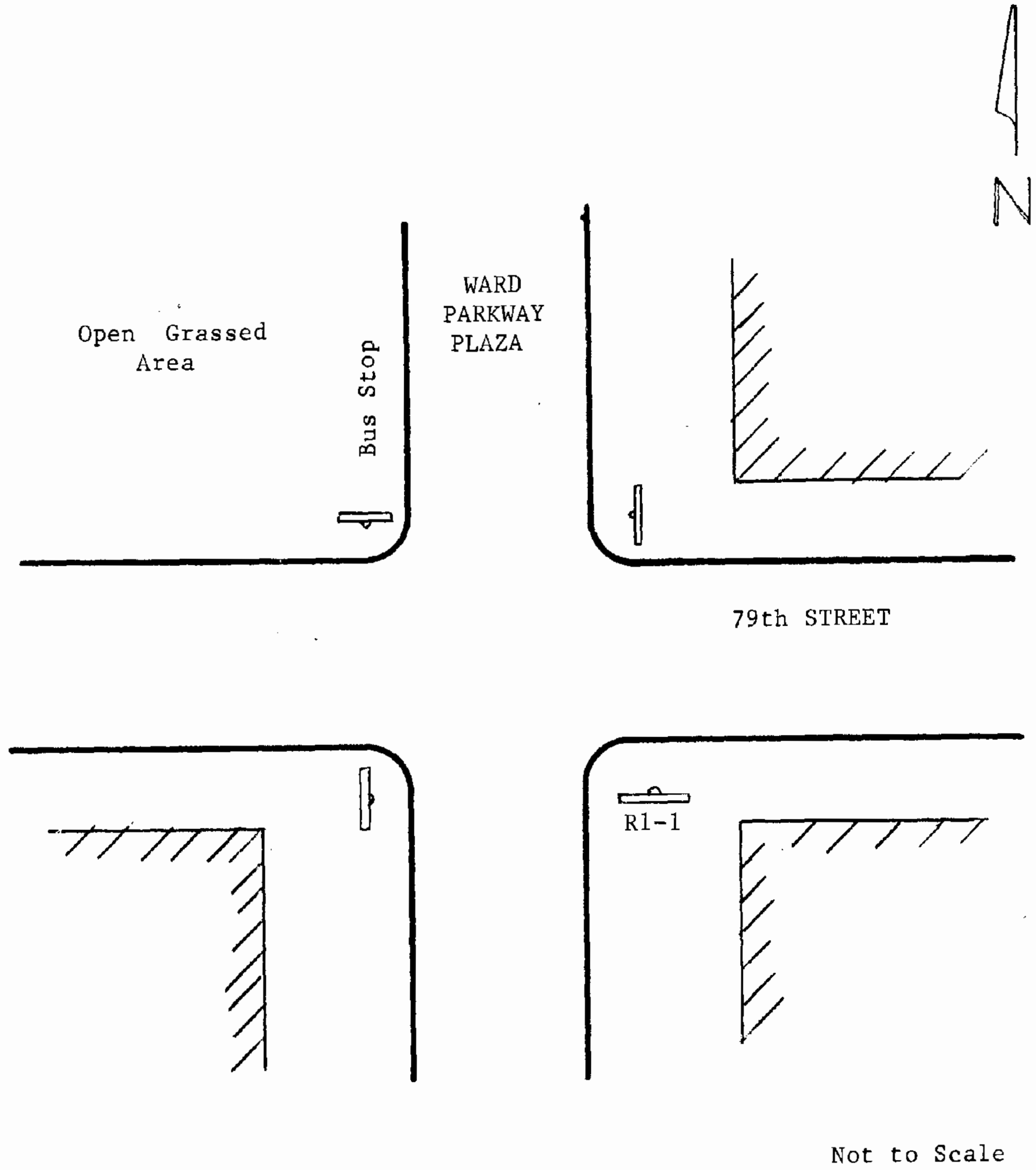

FIGURE 39. SITE DIAGRAM. 79th AND WARD PARKWAY PLAZA. (KANSAS CITY, MISSOURI. November 1, 1983)

FIGURE 40. NOTICE SIGN BENEATH STOP SIGNS ON 79TH STREET PRIOR TO CONVERSION. (KANSAS CITY, MISSOURI)

FIGURE 41. NOTICE SIGN BENEATH STOP SIGN ON WARD PARKWAY PLAZA PRIOR TO CONVERSION. (KANSAS CITY, MISSOURI)

FIGURE 42. CAUTION SIGN BENEATH STOP SIGNS REMAINING ON WARD PARKWAY PLAZA AFTER CONVERSION. (KANSAS CITY, MISSOURI)

FIGURE 43. CLOSE UP OF CAUTION SIGN IN FIGURE 42

TABLE 15. PEAK HOUR COUNTS ON 79TH STREET AFTER CONVERSION

79TH STREET (EB & WB)*

Time/Date	Nonstop	Stop/hesitated	Total	% Stopping or Hesitating
4:00 - 6:00 p.m. 11/1/83	428	237	665	35.6
7:00 - 9:00 a.m. 11/2/83	283	140	423	33.1

* Stop signs removed on this street.

TABLE 16. PEAK HOUR COUNTS ON WARD PARKWAY PLAZA AFTER CONVERSION

WARD PARKWAY PLAZA

Time/Date	Traffic Direction	Stopped (% Total)	Running Stop	Non Stop	Erratic Maneuver	Total
4:00 - 6:00 p.m. 11/1/83	NB SB	54 (58.1%) 58 (29.9%)	33 114	2 5	4 17	93 194
7:00 - 9:00 a.m. 11/2/83	NB SB	136 (90.7%) 68 (79.1%)	12 16	0 0	2 2	150 86

Traffic eastbound and westbound on 79th was thought by local personnel to be intercounty commuter traffic. Likewise, southbound traffic on Ward Parkway Plaza was thought to be heavily commuter traffic avoiding congested traffic conditions on nearby arterials.

Observations during the 30-day period after conversion by the Kansas City Traffic Engineering Division revealed that approximately 10 calls were received from interested citizens after the "NOTICE OF REMOVAL" signs were posted. This was far below the usual amount of calls received when similar intersections were converted in the past. No accidents occurred at the intersection during the 30-day period after conversion.

8.0 CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

This study identified several jurisdictions around the country where safe multiway stop sign conversion procedures have been widely practiced for many years. For example, Peoria, Illinois began conversion of unwarranted multiway stop signs over 25 years ago (23). As a result of this program, the number of four-way stops was reduced from 41 to 18. Peoria also found that the conversions won public support and improved driver obedience at "justified" stop signs.

Philadelphia has recently initiated a program to remove unwarranted multiway stop signs, as have Dayton, Ohio; Bloomingdale, Illinois; and other cities in Michigan, California, Missouri, Tennessee, and Wisconsin.

Not all jurisdictions with effective procedures were visted due to travel limitations. However, the procedures documented in this report, which were utilized in the pilot test cities, are felt to be representative of the best conversion procedures.

The results of the field tests demonstrate that the recommended procedures herein are effective for safely converting multiway stop intersections to lesser forms of control.

The recommended conversion procedure presented in Section 6 may be used in its entirety, or each local jurisdiction may determine which items (steps) in the recommended conversion procedures (RCP) are appropriate for its use and specifically for a given intersection. For example, if an intersection has (1) unwarranted stop signs (shown by an engineering study, according to MUTCD), (2) low minor street and low-to-moderate street volumes, (3) no prior accident experiences, and (4) excellent sight distance, a decision may be made to not use the 30-day notice signs. On the other hand, if substantial public opposition to the conversion is anticipated, the pre-conversion phase should be modified to include public information/education sessions in order to show the public the facts pertaining to unwarranted multiway stop control.

Even if all of the RCP steps are not followed, the procedure provides a good checklist to ensure that all major points and elements are considered.

8.2 RECOMMENDATIONS

It is recommended that further studies be conducted at the conversion sites. In particular, after 1 year (and also after 3 years) accident studies should be done at each converted intersection and a before-and-after accident analysis conducted to identify any problems that may exist and/or to verify that the conversion was done with minimum hazard. Specifically, the 1-year accident analysis should be conducted for the pilot intersections converted in this project.

Long-range observation studies should also be undertaken to determine whether the removal of unwarranted stop signs has increased the observance rate at remaining warranted ones.

Finally, the process should be started to request that the National Committee consider the two advance notice signs and the warning sign ("CAUTION, CROSS TRAFFIC DOES NOT STOP") for inclusion in the MUTCD and the Traffic Control Devices Handbook.

APPENDIX A

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APPENDIX B

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APPENDIX C

CANDIDATE SIGN MESSAGES

The intersection of Elm Street and Green Street was controlled previously by 4-way stop signs. (See Figure 1 below.)

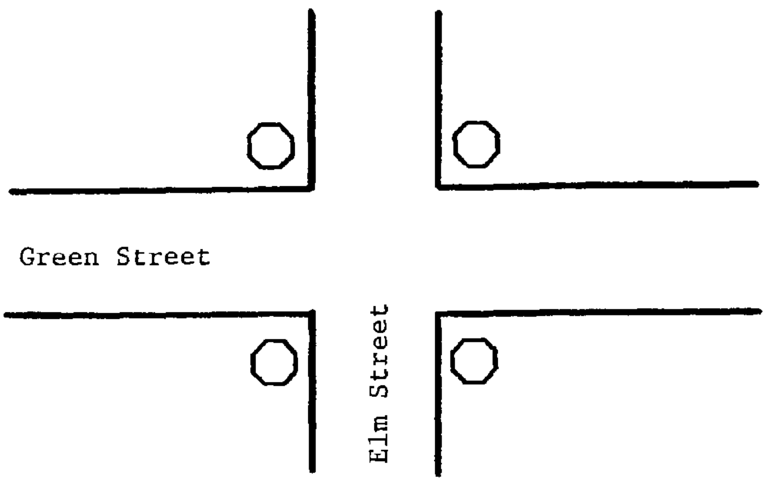


FIGURE 1. 4-WAY STOP

The city council has decided to change the control to Stop signs on Elm Street only. (See Figure 2 below.)

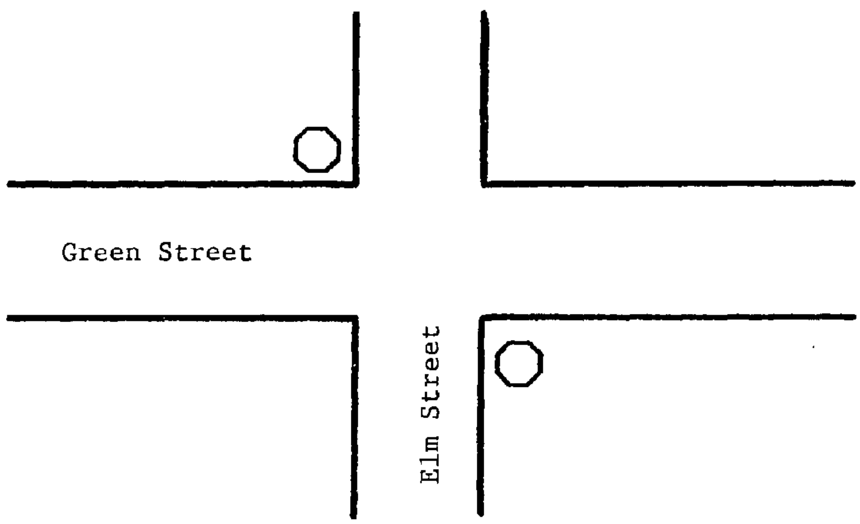


FIGURE 2. 2-WAY STOP

The city traffic engineer is considering different sign formats to inform/warn drivers of the change.

On the following pages are several sign messages that he is considering to inform/warn motorists of the changed condition.

Would you please rank each of these signs in the order that you feel will best inform/warn the drivers of the change. (Rank the sign that you consider the best as no. 1, the next best as no. 2, etc., until you have ranked all the signs.)

SIGN # 1

CAUTION

WATCH FOR
THRU TRAFFIC

RANK ____________

SIGN # 2

CAUTION

WATCH FOR
CROSS TRAFFIC

RANK ____________

SIGN # 3

CAUTION

CROSS TRAFFIC
DOES NOT
STOP

RANK ____________

SIGN # 4

CAUTION

CROSS STREET
DOES NOT
STOP

RANK ____________

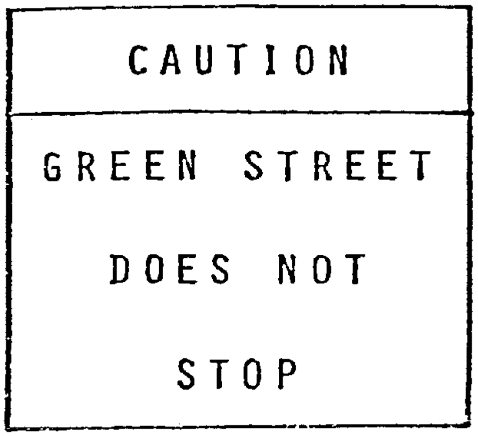
SIGN # 5

CAUTION

NO LONGER
4-WAY STOP

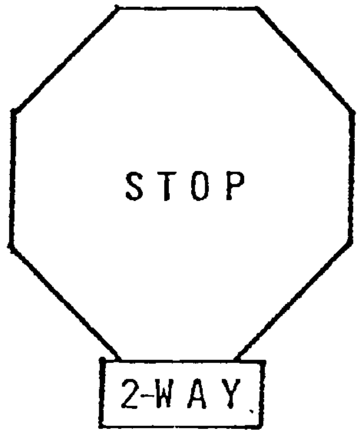
RANK ____________

SIGN # 6



RANK______________

SIGN # 7



RANK________________

Do you have any suggestions for a better sign format than the signs that you have already ranked? If so, would you please include your idea(s) on the lines below.

APPENDIX D

VIEWING SEQUENCE OF CANDIDATE SIGNS

Order of Signs for Testing At FHWA

Sequence 1

1. CAUTION WATCH FOR THRU TRAFFIC
2. CAUTION WATCH FOR CROSS TRAFFIC
3. CAUTION NO LONGER 4-WAY STOP
4. CAUTION CROSS TRAFFIC DOES NOT STOP
5. 2-WAY PLACARD
6. 2-WAY & CAUTION CROSS TRAFFIC DOES NOT STOP
7. 2-WAY & CAUTION NO LONGER 4-WAY STOP
8. 2-WAY & CAUTION WATCH FOR CROSS TRAFFIC
9. 2-WAY & CAUTION WATCH FOR THRU TRAFFIC
10. NO STOP ON CROSS STREET (BLACK & WHITE)
11. CAUTION, NO 4-WAY STOP

Six different sets of questions, 50 subjects.

Order of Signs for Army Reserve Testing

Sequence 2, Group 1

1. 2-WAY
2. 2-WAY & CAUTION NO LONGER 4-WAY STOP
3. 2-WAY & CAUTION CROSS STREET DOES NOT STOP
4. 2-WAY & CAUTION WATCH FOR THRU TRAFFIC
5. 2-WAY & CAUTION WATCH FOR CROSS TRAFFIC
6. CAUTION NO LONGER 4-WAY STOP
7. CAUTION CROSS STREET DOES NOT STOP
8. CAUTION WATCH FOR THRU TRAFFIC

9. CAUTION WATCH FOR CROSS TRAFFIC

10. CAUTION NO 4-WAY STOP

11. CAUTION NO STOP ON CROSS STREET (BLACK & WHITE)

Two different sets of questions, 20 subjects.

<u>Sequence 3, Group 2</u>

1. 2-WAY
2. 2-WAY & CAUTION, CROSS STREET DOES NOT STOP
3. 2-WAY & CAUTION, WATCH FOR THRU TRAFFIC
4. 2-WAY & CAUTION, WATCH FOR CROSS TRAFFIC
5. 2-WAY & CAUTION, NO LONGER 4-WAY STOP
6. CAUTION, CROSS STREET DOES NOT STOP
7. CAUTION, WATCH FOR THRU TRAFFIC
8. CAUTION, WATCH FOR CROSS TRAFFIC
9. CAUTION, NO LONGER 4-WAY STOP
10. CAUTION, NO 4-WAY STOP
11. NO STOP ON CROSS STREET (BLACK & WHITE)

Two different sets of questions, 18 subjects.

<u>Sequence 4, Group 3</u>

1. 2-WAY
2. 2-WAY & CAUTION, WATCH FOR THRU TRAFFIC
3. 2-WAY & CAUTION, WATCH FOR CROSS TRAFFIC
4. 2-WAY & CAUTION, NO LONGER 4-WAY STOP
5. 2-WAY & CAUTION, CROSS TRAFFIC DOES NOT STOP
6. CAUTION, WATCH FOR THRU TRAFFIC
7. CAUTION, WATCH FOR CROSS TRAFFIC

Sequence 4, Group 3 (continued)

8. CAUTION, NO LONGER 4-WAY STOP

9. CAUTION, CROSS TRAFFIC DOES NOT STOP

10. CAUTION, NO 4-WAY STOP

11. NO STOP ON CROSS STREET

Two different sets of questions, 4 subjects.

Order of Signs for Testing at Maryland State Police

Sequence 5

1. CAUTION, WATCH FOR THRU TRAFFIC

2. CAUTION, WATCH FOR CROSS TRAFFIC

3. CAUTION, CROSS TRAFFIC DOES NOT STOP

4. CAUTION, NO LONGER 4-WAY STOP

5. 2-WAY

6. 2-WAY; CAUTION, NO LONGER 4-WAY STOP

7. 2-WAY; CAUTION, WATCH FOR THRU TRAFFIC

8. 2-WAY; CAUTION, WATCH FOR CROSS TRAFFIC

9. 2-WAY; CAUTION, CROSS TRAFFIC DOES NOT STOP

10. CAUTION, NO 4-WAY STOP

11. NO STOP ON CROSS STREET

Two different sets of questions, 37 subjects.

Order of Signs for Testing University of Maryland Senior Class

Seouence 6

1. CAUTION, WATCH FOR CROSS TRAFFIC

2. CAUTION, CROSS TRAFFIC DOES NOT STOP

3. CAUTION, NO LONGER 4-WAY STOP

4. CAUTION, WATCH FOR THRU TRAFFIC

Sequence 6 (continued)

5. 2-WAY

6. 2-WAY; CAUTION, WATCH FOR CROSS TRAFFIC

7. 2-WAY; CAUTION, CROSS TRAFFIC DOES NOT STOP

8. 2-WAY; CAUTION, NO LONGER 4-WAY STOP

9. 2-WAY; CAUTION, WATCH FOR THRU TRAFFIC

10. CAUTION, NO 4-WAY STOP

11. NO STOP ON CROSS STREET

Two different sets of questions, 30 subjects.

Order of Signs for University of Maryland Physical Education Class

Sequence 7

1. CAUTION, CROSS TRAFFIC DOES NOT STOP

2. CAUTION, WATCH FOR CROSS TRAFFIC

3. CAUTION, NO LONGER 4-WAY

4. CAUTION, WATCH FOR THRU TRAFFIC

5. 2-WAY

6. 2-WAY, CAUTION, CROSS TRAFFIC DOES NOT STOP

7. 2-WAY, CAUTION, WATCH FOR CROSS TRAFFIC

8. 2-WAY, CAUTION, NO LONGER 4-WAY

9. 2-WAY, CAUTION, WATCH FOR THRU TRAFFIC

10. NO STOP ON CROSS STREET

11. CAUTION, NO 4-WAY STOP

Four different sets of questions, 75 subjects.

APPENDIX E

CLASSIFICATION QUESTIONNAIRE

THIS INFORMATION ABOUT YOU IS NEEDED FOR CROSS TABULATION PURPOSES. WE DON'T WANT TO KNOW YOUR NAME, BUT WE WOULD LIKE TO KNOW A FEW FACTS ABOUT YOU. PLEASE CHECK (✓) ONE ANSWER FOR EACH QUESTION EXCEPT AS NOTED.

1. WHAT IS YOUR SEX? ______ FEMALE ______ MALE ____

2. WHAT IS YOUR AGE?

   ______ Under 16 ______ 40 thru 49
   ______ 16 thru 19 ______ 50 thru 59
   ______ 20 thru 24 ______ 60 thru 64
   ______ 25 thru 29 ______ 65 thru 69
   ______ 30 thru 39 ______ 70 or older ____

3. WHAT IS YOUR HIGHEST LEVEL OF SCHOOLING ATTENDED?

   _____ Some high school or less _____ Junior college graduate
   _____ High school graduate _____ College graduate
   _____ Some college _____ Advance degree ____

4. ABOUT HOW LONG HAVE YOU HAD A LICENSE TO DRIVE?

   _____ less than 1 year _____ 10 to 14 years
   _____ 1 to 2 years _____ 15 to 19 years
   _____ 3 to 4 years _____ 20 years or more ____
   _____ 5 to 9 years

5. ABOUT HOW OFTEN DO YOU DRIVE A MOTOR VEHICLE?

   ____ Every day ____ Two to four times a month
   ____ Three or Four times a week ____ Less than four times a month
   ____ Once or twice a week ____ Never

1. What are we supposed to do when we see this sign?

(a) I must stop and then may go if no other traffic is in the way

(b) There is no stop control at this intersection

(c) Other traffic has the right of way

(d) Not certain

2. What are we supposed to do when we see this sign?

(a) I must stop and then may go if no other traffic is in the way

(b) There is no stop control at this intersection

(c) Cross traffic has the right of way

(d) Not certain

3. What are we supposed to do when we see this sign?

(a) Cross street traffic does not stop but I must

(b) Prepare to yield to traffic on the other street if we see any

(c) Traffic on the other street at this intersection should let me proceed after I stop.

(d) Not certain

4. What are we supposed to do when we see this sign?

(a) Cross street traffic does not stop but I must

(b) Yield to other traffic

(c) Traffic on the other street at this intersection should let me proceed after I stop

(d) Not certain

5. What action does this sign imply to you?

(a) I should be careful at this intersection

(b) If no other traffic is in the intersection, I may proceed after stopping

(c) Traffic on the other street does not have to stop, but I do

(d) Not certain

6. What action does this sign imply to you?

(a) I should be careful as I approach this intersection

(b) If no other traffic in interfering, I may proceed after stopping

(c) Traffic on the other street does not have to stop, but I do

(d) Not certain

7. What are we supposed to do when we see this sign?

(a) I must stop and then may go if no other traffic is in the way

(b) There is no stop control at this intersection

(c) Other street has the right of way

(d) Not certain

8. What are we supposed to do when we see this sign?

(a) I must stop and then may go if no other traffic is in the way

(b) There is no stop control at this intersection

(c) Cross street has the right of way

(d) Not certain

9. What action does this sign imply to you?

(a) I should be careful as I approach this intersection

(b) If no other traffic is interfering, I may proceed after stopping

(c) Traffic on the other street does not have to stop, but I do

(d) Not certain

10. What action does this sign imply to you?

(a) I should be careful as I approach this intersection

(b) I must stop and if no other traffic is interfering, I may proceed

(c) Traffic on the other street does not have to stop, but I do

(d) Not certain

11. What action does this sign imply to you?

(a) I should be careful as I approach this intersection.

(b) I must stop but may proceed as soon as the intersection is clear of traffic.

(c) Traffic on the other street does not have to stop, but I do

(d) Not certain

RATING OF WARNING SIGNS

I - SIGN WARNING THAT CROSS STREET WILL NOT STOP - BEGINNING -----

/_7 EXCELLENT /_7 VERY GOOD /_7 GOOD

/_7 POOR /_7 VERY POOR

II - SIGN INFORMING THAT THE STOP SIGN WILL BE REMOVED ON --------

/_7 EXCELLENT /_7 VERY GOOD /_7 GOOD

/_7 POOR /_7 VERY POOR

A. Now, consider all ___11___ signs which we have reviewed.

(Sketch of all ______________ signs attached)

Which sign would you recommend at the intersection?

(Indicate below or circle on sketch & place 1, 2, 3 by the circled signs)

1st Choice __________ 2nd Choice _________ 3rd choice _________

B. In addition to warning/informing drivers of the intersection, it may be desirable to warn them in advance of the intersection. Which, if any, of these signs would you recommend to warn drivers in advance of the intersection?

1st choice __________ 2nd choice __________ 3rd choice ________

If none, do you have any recommendations? ________________________

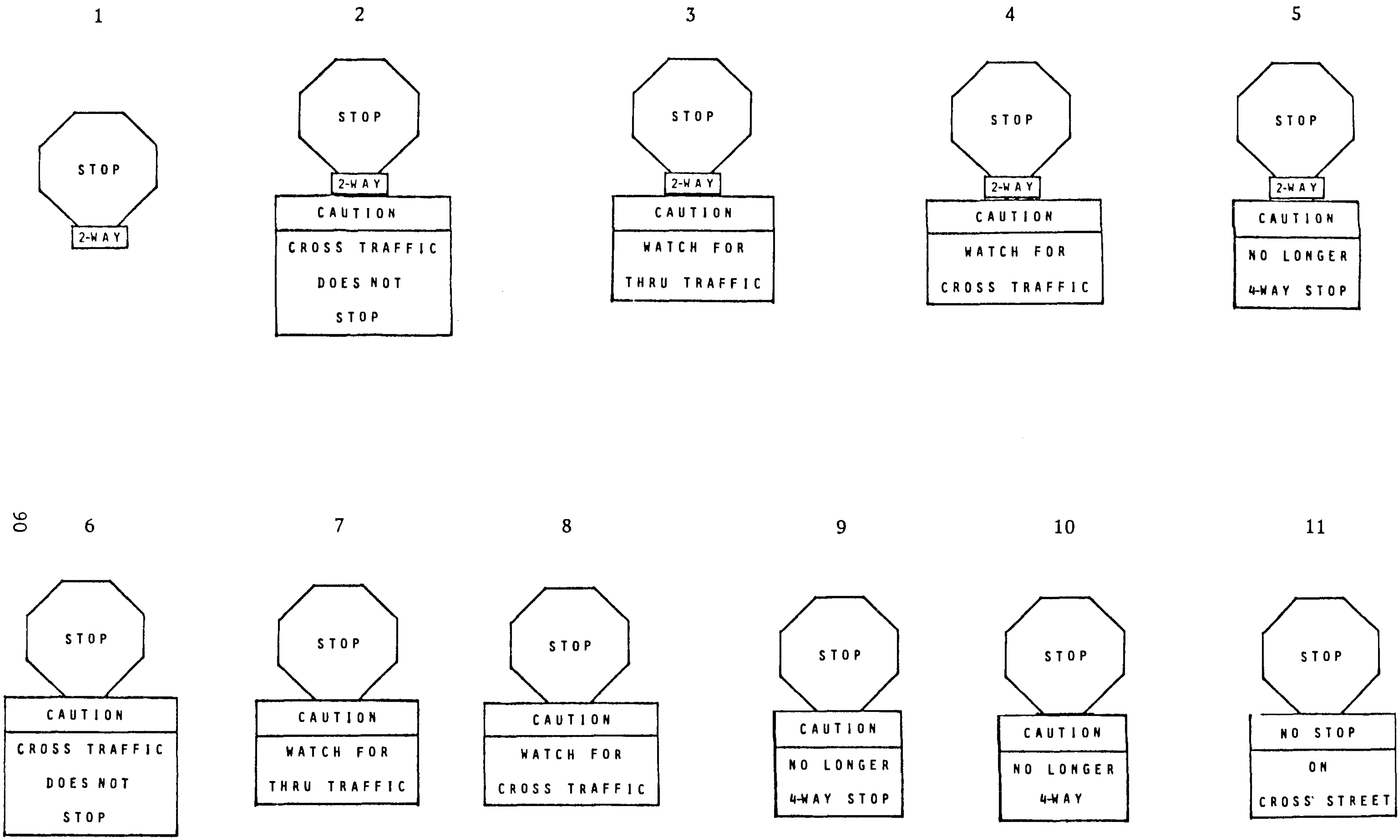
____

____

C. Do you have any suggestions of other signs to inform/warn drivers at this intersection? ____

____

____



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FEDERALLY COORDINATED PROGRAM (FCP) OF HIGHWAY RESEARCH AND DEVELOPMENT

The Offices of Research and Development (R&D) of the Federal Highway Administration (FHWA) are responsible for a broad program of staff and contract research and development and a Federal-aid program, conducted by or through the State highway transportation agencies, that includes the Highway Planning and Research (HP&R) program and the National Cooperative Highway Research Program (NCHRP) managed by the Transportation Research Board. The FCP is a carefully selected group of projects that uses research and development resources to obtain timely solutions to urgent national highway engineering problems.*

The diagonal double stripe on the cover of this report represents a highway and is color-coded to identify the FCP category that the report falls under. A red stripe is used for category 1, dark blue for category 2, light blue for category 3, brown for category 4, gray for category 5, green for categories 6 and 7, and an orange stripe identifies category 0.

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems associated with the responsibilities of the FHWA under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion, and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by balancing the demand-capacity relationship through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements that affect the quality of the human environment. The goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge and technology of materials properties, using available natural materials, improving structural foundation materials, recycling highway materials, converting industrial wastes into useful highway products, developing extender or substitute materials for those in short supply, and developing more rapid and reliable testing procedures. The goals are lower highway construction costs and extended maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural and hydraulic designs, fabrication processes, and construction techniques to provide safe, efficient highways at reasonable costs.

6. Improved Technology for Highway Construction

This category is concerned with the research, development, and implementation of highway construction technology to increase productivity, reduce energy consumption, conserve dwindling resources, and reduce costs while improving the quality and methods of construction.

7. Improved Technology for Highway Maintenance

This category addresses problems in preserving the Nation's highways and includes activities in physical maintenance, traffic services, management, and equipment. The goal is to maximize operational efficiency and safety to the traveling public while conserving resources.

0. Other New Studies

This category, not included in the seven-volume official statement of the FCP, is concerned with HP&R and NCHRP studies not specifically related to FCP projects. These studies involve R&D support of other FHWA program office research.

* The complete seven-volume official statement of the FCP is available from the National Technical Information Service, Springfield, Va. 22161. Single copies of the introductory volume are available without charge from Program Analysis (HRD-3), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.

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