Guidance on the Safe Implementation of Unconventional Arterial Designs

Draft Final Report

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ABSTRACT

Unconventional arterial designs like median u-turns, superstreets, jughandles, continuous flow intersections, and bowties have the potential to significantly reduce delay compared to conventional arterial designs of similar size. One of the reasons designers cite for not using the unconventional designs, however, is concern that drivers will not understand how to negotiate their way through the intersections, particularly when they are new. The purpose of this project was to explore this concern and highlight ways in which it could be alleviated. States where the unconventional designs are already in place were contacted regarding their signing plans and public information procedures. Many of the signing plans are a good starting, if not ending, point for engineers interested in implementing these designs. Public information is another important aspect of implementing the unconventional designs. Information regarding the designs can be distributed to the driving public in a variety of ways, including, but not limited to, pamphlets, flyers and newspaper articles. The results of this effort indicate that the five unconventional arterial designs can be implemented safely through the use of signing plans and efficient public information campaigns.

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The views and opinions expressed in this paper are those of the authors and do not necessarily reflect the views and opinions of the STC, the NCDOT, the Michigan DOT, the New Jersey DOT, or North Carolina State University.

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1. INTRODUCTION

Many signalized intersections in the U.S. suffer from congestion and long queues and delays. Congestion on urban and suburban arterials is an ever-present traffic problem. The issue of congestion is so broad that no one solution will fix the problem. Therefore, it is important to mold congestion solutions to fit specific problem areas. From traffic-actuated signals to multiple left-turn lanes to parallel one-way streets, transportation engineers have tried many traditional approaches to relieving this problem. Although these approaches are sometimes successful, there is a need to explore additional options. Unconventional alternatives may provide a new way of tackling these issues.

Engineers should consider alternatives that focus on treating left-turns to and from arterials, as they are the cause of many operational problems. These "unconventional" alternatives focus on reducing delay to through vehicles, reducing conflict points at intersections, and separating the conflict points that remain (1). The unconventional alternatives that are being considered for the purpose of this project are median u-turns (left turns to and from the arterial required to use directional median crossovers), superstreets (all left turns and the cross-street through movements must use directional median crossovers), bowties (a form of median u-turn using roundabouts instead of median crossovers), continuous flow intersections (ramp to the left of the arterial upstream of the main intersection to handle traffic turning left from the arterial), and jughandles (ramps diverge from the right side of the arterial to accommodate all turns from the arterial) (2). These designs have potential for widespread implementation in the short term. Unfortunately, these alternatives, in providing a different and sometimes new approach to attacking congestion, may cause more driver confusion than conventional arterials.

With the implementation of new and unfamiliar arterial designs, there is always the concern about driver understanding. The new designs may reduce the congestion at intersections, but only if the drivers effectively navigate them. Therefore, the question arises: How should agencies communicate to the driver the correct and safe way to utilize a new arterial design?

When dealing with new traffic designs, driver expectancy is an extremely important factor. According to FHWA's *Driver Expectancy in Highway Design and Traffic Operations* (3), "expectancy relates to a driver's readiness to respond to situations, events, and information in predictable and successful ways." Traffic operations, traffic control devices, and geometrics that are unfamiliar to or "unexpected" by drivers, violate this concept. When driver expectancy is violated, the driver may respond in a confused, frustrated, slow, or even dangerous manner. Therefore, it is important that the road user not only expects what is ahead, but understands how to make his way safely. When introducing a new traffic pattern, drivers need to be aware, ahead of time, of what is expected of them.

Transportation engineers and officials, enforcement officers, and the driving public all have a vested interest in these issues. All of these parties will need to be involved in the process of implementing the five designs for them to be successful.

This project will recommend to designers how to safely implement unconventional designs. This project report will discuss which signs are effective for particular designs (including cost data), what public relations activities are most effective in informing drivers of unusual new intersections, and what types of enforcement are needed.

2. DESIGNS

The unconventional arterial designs that are the focus of this project all basically share the same operational mode: they reroute left-turn movements.

Probably the most recognized "new" type of arterial design is the roundabout. The roundabout design operates without the use of signals. It is a circular roadway that has a continuous circulating traffic flow; drivers enter where there is an appropriate gap. Entering traffic yields to the traffic in the roundabout. Although not one of the designs being studied, the roundabout is now relatively popular. As it was a "new" design that caused drivers to adapt to a new operation, some information regarding roundabouts may be referenced. Roundabout implementation will be a good analogy for unconventional design implementation.

The roundabout has effectively eased its way into mainstream traffic operations. As most drivers have become comfortable with navigating this design, there is hope that the five unconventional designs of interest here should, in time and if widely implemented, be easily recognized as well.

2.1. Descriptions and Signing Plans

2.1.1. Median U-Turn

The median u-turn, shown in Figure 2-1, requires left-turning vehicles to and from the arterial to use directional median crossovers. Left turns are prohibited at the main intersections. Vehicles wishing to turn left from the main arterial to the minor arterial or collector must continue through the intersection, make a u-turn at the crossover and then make a right turn back at the intersection. Vehicles wishing to turn left onto the arterial must first turn right, make a u-turn at the crossover and then proceed through the intersection. The most prominent user of median u-turns in the United States, the Michigan Department of Transportation (DOT) has over 1,000 miles in service (1).

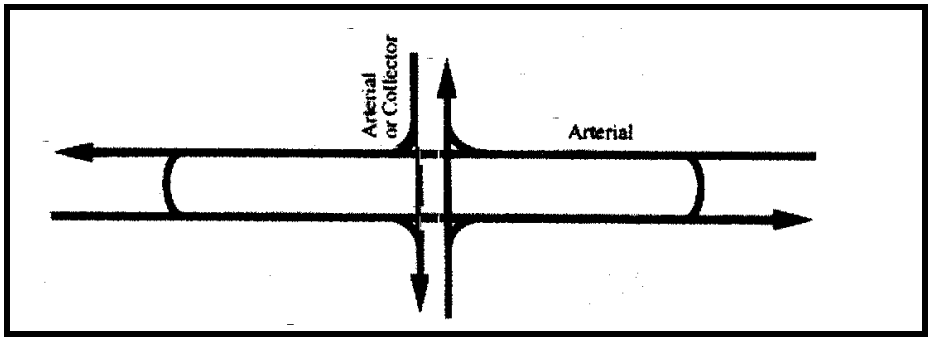

Figure 2-1. Median U-turn

The typical signing plan used by the Michigan DOT consists of a series of regulatory and guide signs (Appendix A). As shown in a table in Appendix B, all of the regulatory signs used in this plan are in the *Manual on Uniform Traffic Control Devices* (MUTCD) (5).

This typical method of signing median u-turns has been in place for many years. This signing plan has been and remains, according to several Michigan DOT traffic engineers, an effective one.

2.1.2. Superstreet

The superstreet design, shown in Figure 2-2, is an alternative that eliminates through and left-turn movements from the minor street. These movements are rerouted to the directional crossover on the major street. The superstreet alternative was originated by Richard Kramer, a traffic engineer in Alabama. There are few full implementations of the superstreet alternative (1).

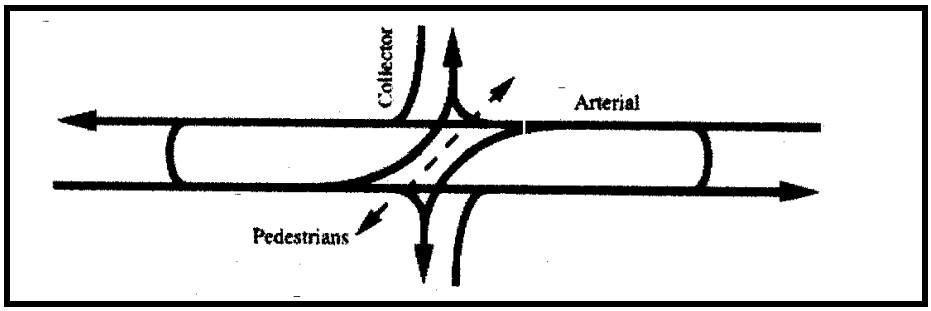

Figure 2-2. Superstreet

The research team was able to locate an implemented superstreet design in Kent County, Maryland (Appendix A). A site visit provided information on the signs and marking. The superstreet, at the intersection of US 301 and Galena Road, is unsignalized and follows the operational procedure described previously. The majority of the signs used at this particular intersection are MUTCD standard or assemblies of MUTCD standard signs. Appendix B displays pictures of some of the signs, including the more innovative ones.

After observation of this intersection, the signing plan seemed to be an effective one. There did not appear to be any driver confusion, which could have been indicated by late lane changes, erratic braking, or decreased vehicle speed on approach. However, the addition of a diagrammatic sign on the minor street approach to convey to the driver how to complete the through or left turn movement would be helpful. This signing plan seemed effective for this section of US 301, where the traffic was light to moderate. This same signing plan also would seem appropriate in a suburban area. However, if the superstreet design were located in a busier area, signalization may be necessary. If there is a higher volume on the major street, entry from the minor street may become difficult.

2.1.3. Jughandle

The jughandle design, shown in Figure 2-3, uses ramps diverging from the right side of the arterial to accommodate all turns from the arterial (2). This design eliminates all turns from the main arterial at the intersection. Approaching the intersection, the vehicles wishing to make right or left turns use the ramp on the right side. Those turning left will

take the ramp, make the left onto the cross street and then proceed through the intersection. Those turning right will simply take the ramp and continue right.

The New Jersey Department of Transportation (NJDOT) has used and continues to use jughandles on hundreds of miles of heavy-volume arterials (2).

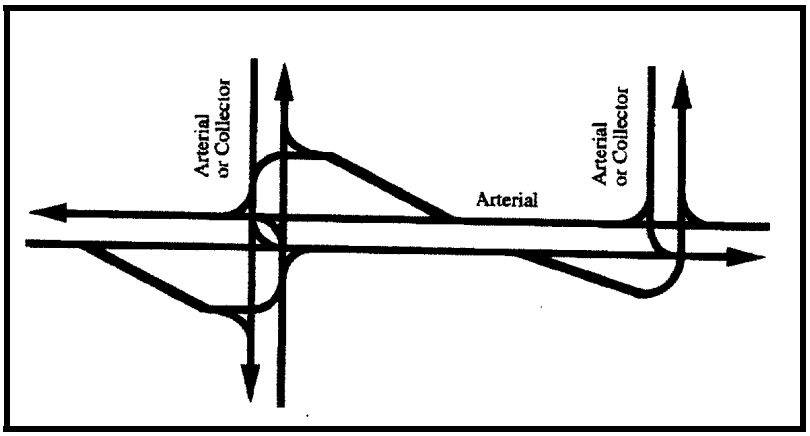

Figure 2-3. Jughandle

The NJ DOT provided typical signing and marking plans for a variety of jughandle designs (Appendix A). There is a combination of regulatory and guide signs. Again, not all of the signs are MUTCD standard (Appendix B). Several NJDOT traffic engineers believe that their typical signing plans have been and continue to be effective. A site visit to several intersections in New Jersey provided the research team with the opportunity to drive a variety of jughandle designs. Based on the experience of a first-time jughandle driver, the method of signing proved adequate and effective.

2.1.4. Continuous Flow Intersection

The continuous flow intersection design (CFI), shown in Figure 2-4, uses a ramp to the left of the main arterial and a ramp to the right of the minor arterial or collector. Left-turning vehicles from the main street take the left side ramp to the minor street prior to reaching the intersection. Right-turning vehicles from the minor street take the right side ramp to the major street prior to entering the intersection.

This design, patented by Francisco Mier (U.S. Patent Number 5049000), was first used in the U.S. in Long Island, New York and has since been used several times in Mexico (2).

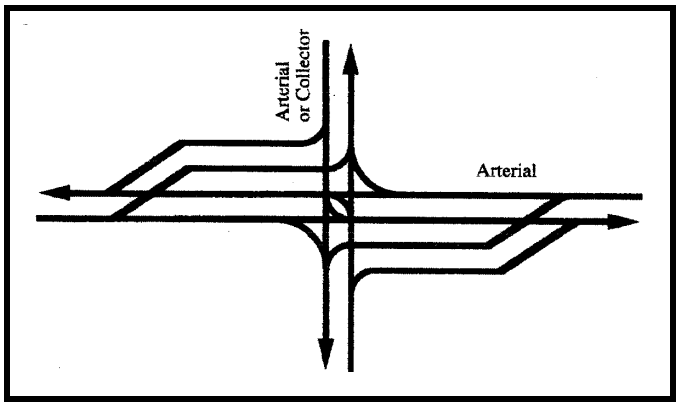

Figure 2-4. Continuous Flow Intersection

Although most of these designs have been implemented in Mexico, the research team visited a partial CFI in Prince Georges County, Maryland (Appendix A). The "continuous flow" left side ramp was located on the minor street. Located at the T-intersection of MD 210 and MD 228, there are many signs directing drivers. The signing plan used at this particular intersection incorporates many MUTCD standard signs. This signing plan also uses several overhead signs. Although more than adequately communicating directions to the driver, the overhead signs could likely be replaced with roadside signs at other intersections.

Although this signing plan is for a partial intersection, it would be effective for a full CFI as well. Whether the continuous flow portions were on the minor or major arterial, the same signing method could be used.

2.1.5. Bowtie

The bowtie, shown in Figure 2-5, is a design that accommodates all left turns on the cross street. The bowtie uses roundabouts on the cross street to accommodate left turns instead of directional crossovers across a wide median (1). Again, with left turns prohibited, the vehicles wishing to turn left will make a right turn at the intersection, enter the roundabout on the minor street, and then come back through the intersection.

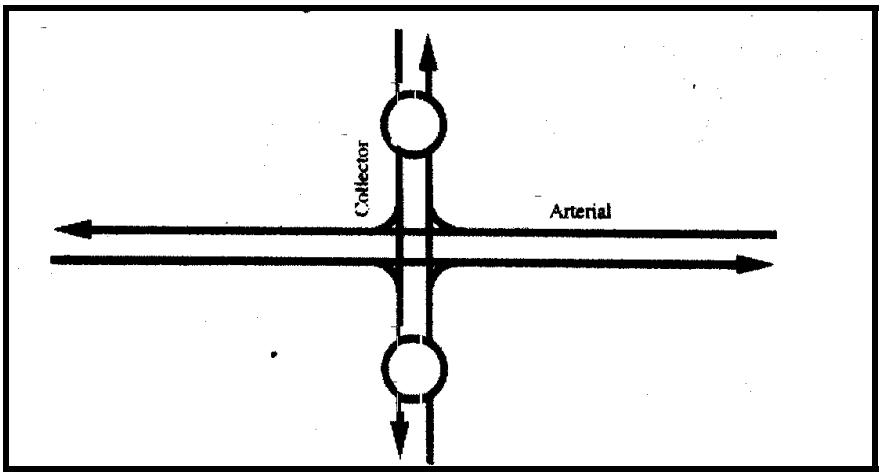

Figure 2-5. Bowtie

The bowtie is the only design mentioned that has not already been implemented at some location. Because there is no current implementation for this design, the research team developed a signing plan. As shown in Appendix A, the signing plan essentially combines the signing plans of the roundabout (obtained from the North Carolina Department of Transportation), jughandle, and median u-turn with a few innovative additions. As the signing plans for those designs appear to be effective, the bowtie designs signing plan should be equally adequate.

2.2. Movement Evaluation

The basic issue in developing signing plans for these designs is to communicate ways in which they differ from conventional intersections from the driver's point of view. To explore these differences, the project team developed a matrix (Table 2-1) illustrating the number of "unnatural and altered movements" required to navigate each design. An unnatural movement is a movement that requires a different course of action than a typical intersection, i.e., to make a left turn, a driver must turn right and then go straight. An altered movement is a movement that essentially requires the same course of action, but at a different location, i.e., a right turn is still permissible, but occurs before or after the intersection.

The matrix includes four conventional intersection types, the five unconventional designs of interest, and the roundabout. There are sixteen movements considered, including u-turns. The matrix shows that the roundabout contains the largest number of unnatural and altered movements. The five designs of interest fall in between the conventional intersections and the roundabout, with the jughandle containing the fewest number of unnatural movements.

A second matrix (Table 2-2) illustrates the pedestrian movements required to safely cross these designs. This is evaluated by taking into account the number of roadways crossed, the number of crossings of free-flowing roadways, and the status of the right-turn movement (free-flowing or controlled). The designs are then ranked according to lowest

Table 2-1. Unnatural Vehicle Movement Matrix

	Vehicle Movements																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total	Rank
Conventional Intersection (1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Conventional Intersection (2)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Conventional Intersection (3)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Conventional Intersection (4)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Median U-Turn	1	2	0	0	2	2	0	0	1	2	0	0	2	2	0	0	14	6
Superstreet	1	0	0	0	2	2	2	0	1	0	0	0	2	2	2	0	14	6
CFI	2	2	0	0	2	0	0	1	2	2	0	0	2	0	0	1	14	6
Jughandle	2	2	0	1	0	0	0	0	2	2	0	1	0	0	0	0	10	5
Bowtie	2	2	0	0	1	2	0	0	2	2	0	0	1	2	0	0	14	6
Roundabout	2	2	1	0	2	2	1	0	2	2	1	0	2	2	1	0	20	10

unnatural movement (2 pts) -- a movement that requires a different course of action; i.e. to make a left turn, driver must turn right and then go straight

altered movement (1 pt) -- a movement that essentially requires the same course of action, but at a different location; i.e. a right turn is still permissable, but occurs before or after the intersection

"natural" movement (0 pts)

1 -- No median and free right turn
2 -- Median and no free right turn
3 -- No median and no free right turn
4 -- Median and free right turn

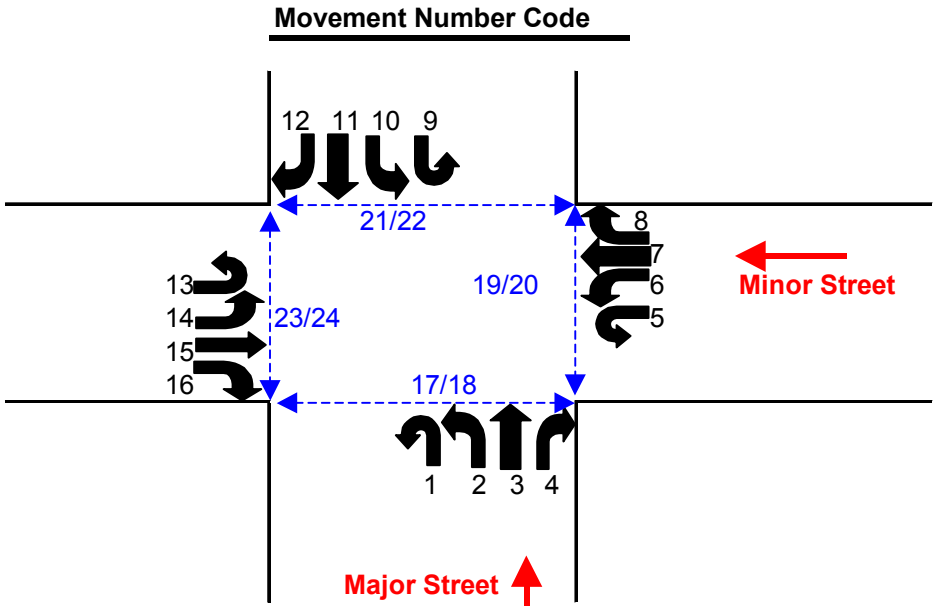

Table 2-2. Pedestrian Movement Matrix

	Pedestrian Movements													
	Number of Roadways Crossed				Number of Free-Flowing Crossings				Right-turn movement Free-flowing(1), Controlled (0)					
	17/18	19/20	21/22	23/24	17/18	19/20	21/22	23/24	17/18	19/20	21/22	23/24	TOTAL	RANK
Conventional Intersection (1)	1	1	1	1	0	0	0	0	1	1	1	1	**8**	**5**
Conventional Intersection (2)	2	1	2	1	0	0	0	0	0	0	0	0	**6**	**3**
Conventional Intersection (3)	1	1	1	1	0	0	0	0	0	0	0	0	**4**	**1**
Conventional Intersection (4)	2	1	2	1	0	0	0	0	1	1	1	1	**10**	**6**
Median U-Turn*	2	1	2	1	0	0	0	0	0	0	0	0	**6**	**3**
Superstreet*	2	1	2	1	2	0	2	0	1	0	1	0	**12**	**7**
CFI*	3	2	3	2	2	2	2	2	1	1	1	1	**22**	**10**
Jughandle*	3	2	3	2	1	1	1	1	1	0	1	0	**16**	**8**
Bowtie	1	1	1	1	0	0	0	0	0	0	0	0	**4**	**1**
Roundabout*	2	2	2	2	2	2	2	2	1	1	1	1	**20**	**9**

Movements 17/18 and 21/22 are crossing the major street.
Movements 19/20 and 23/24 are crossing the minor street

*Assuming medians

Conventional Intersections:

1 -- No median and free right turn
2 -- Median and no free right turn
3 -- No median and no free right turn
4 -- Median and free right turn

score. One of the conventional intersections (no median and no free right turn) and the bowtie design, followed by another conventional intersection (median and no free right turn) and the median u-turn design proved to be the most "pedestrian friendly." The roundabout and continuous flow intersection proved to be the most difficult for pedestrians to navigate.

The roundabout ranks last or close to last in both matrices. There has been an increase in the number of roundabouts being constructed in North Carolina and other states and drivers and pedestrians have gotten used to the designs very quickly. The more exposure drivers have to the unconventional designs, as with the roundabout, the more likely they are to become familiar with it.

2.3. Cost Data

The NCDOT's Traffic Engineering and Safety Systems Branch provided the research team with cost estimates on some of the signs used with these designs. A table in Appendix B displays this cost information. For each of the five unconventional designs (including two types of jughandles), a matrix in Appendix B includes the signs, quantity used in each design, MUTCD standard information (sign number, section, type), dimensions, and costs (including sign cost, mounting cost, installation cost and a 15% mobilization fee).

From least expensive to most expensive, the designs of interest ranked as follows: median u-turn ($7800), bowtie ($12,000), jughandle ($13,000), superstreet ($105,000), and continuous flow intersection ($205,000). The reason for the large difference between the first three designs and the latter two is the use of overhead signs. The superstreet has two overhead signs, one on each of the minor street approaches. The continuous flow intersection signing plan has three overhead signs, all on the southbound approach.

Cost reduction is possible with the superstreet and continuous flow designs. The two overhead signs used in the superstreet intersection convey to the drivers that they must stop ahead and can only turn right at the intersection. Because of the location of the signs and the other signs surrounding them, it appears that the overhead signs are the clearest way to communicate to the drivers what they are to do. However, because the minor approach (at this particular intersection) is one lane in each direction, the message on the overhead sign can be communicated with a roadside sign. We recommend, at this early stage in the development of the superstreet design, ground-mounted guide signs on the minor street if there is just one lane and overhead signs if there are multiple lanes. If the signs were ground-mounted, the total cost of the signing plan would be $12,000.

In the continuous flow intersection design, the use of the three overhead signs does not seem to be absolutely necessary. The overhead signs are guide signs used to indicate which lanes the driver needs to be in to go to a particular destination. The same message could be communicated as clearly without the use of overhead masts, particularly since the left turn is only an altered movement and the through and right turn are unchanged. The destination signs could be mounted on the roadside with directional arrows or words

to communicate the same message as the overhead signs. If the signs were mounted in the ground, the total cost of the signing plan would be reduced to $23,000.

Pavement markings, although not the focus of discussion in this report, may be necessary in some of the unconventional design plans. The pavement markings (lines) are priced per linear foot. The average cost in North Carolina is approximately $0.35 per linear foot for 4-inch lines and $75 for symbols (i.e. arrows). The addition of pavement markings to any of the plans could result in an increase in cost of several thousand dollars.

Three of the five unconventional designs (median u-turn, superstreet, and continuous flow) also may require additional signals at the crossover locations depending upon traffic volumes and other variables. Extra signals are approximately $60,000 each plus the cost of interconnection.

3. PUBLIC INFORMATION AND EDUCATION

3.1. Driver Understanding

One of the most important factors in driver understanding relates to driver expectancy. A new sign or intersection operation may not be necessarily hard to understand when looking at a plan view, but by nature of its appearance, the driver can be surprised or even confused.

To provide signs for an intersection, it is important to know what would make a signing plan effective or ineffective based on driver expectancy. According to the FHWA's *Driver Expectancy in Highway Design and Traffic Operations*, the basic driving task consists of three performance levels – control, guidance, and navigation. Each level involves different acts and information sources. Control refers to the driver's interaction with the vehicle itself. The driver receives information based on the response of the vehicle to his/her actions. Guidance has to do with the driver's maintenance of a safe speed and path. The driver receives information from the highway (geometry, hazards, etc.), traffic (speed, gaps, etc.), and traffic control devices (signs and marking). Navigation deals with the activities involved in planning and executing a trip from origin to destination. Information here comes from maps, signs, and verbal directions.

There are two types of driver expectancies: a priori and ad hoc (3). A priori expectancies are long term and are based on past experience or learned actions. Ad hoc expectancies are more short term and are based on site-specific practices and situations encountered while driving. So, it is necessary, when implementing new designs, to initially tackle the ad hoc expectancy requirement and eventually progress to a priori expectancy. As these designs become more widely used, drivers will understand their operation and know what to expect when they approach them.

In the FHWA's *Driver Expectancy* document, a useful "Detailed Expectancy Checklist" is provided (Appendix C). The checklist reviews a variety of items including land use, road type and surface, sight distances, traffic patterns, signals, markings, signs, and missing information. The research team completed a checklist for each of the five designs, based on drives through four of the five designs. The completed checklists, shown in Appendix C, emphasized the unusual traffic patterns and any signs that were surprising or confusing to the driver. The use of this Expectancy Checklist proved helpful when evaluating the signing plans of the various designs.

3.2. Public Education

With regards to public information, for those states, such as Michigan and New Jersey, that began implementing one or more of these alternatives many years ago, no one can clearly recall what information was initially given to drivers, if any.

There is a variety of ways to educate the public on new traffic patterns and operations. A few of the main ways are informational pamphlets/brochures, press releases and driver

educational classes or programs. Informational pamphlets/brochures allow drivers to have something tangible to refer to at their leisure. Several brochures are shown in Appendix D (7). Press releases get the media involved and therefore increase the reach of the information. Educational programs provide hands-on instruction to particular groups of the driving population, such as elderly or young (new) drivers. The dissemination of pertinent information to drivers can be facilitated through the use of already accessible resources, including driver's license offices, driving schools, motor vehicle organizations (i.e. AAA), trucking associations, and state welcome centers.

3.2.1. Texas Vital Signs Campaign

An example of a successful public traffic control device information campaign is the "Vital Signs" campaign conducted by the Texas Department of Transportation (TXDOT) and the Texas Transportation Institute. The two organizations partnered to put together educational programs and a driver information campaign. In terms of educational programs, the partnership focused on revising descriptions in the *Texas Drivers Handbook*, revising the educational curriculum for driver education and driver safety courses to emphasize selected traffic control devices, and developing driver outreach materials (8).

With regards to the driver information campaign, the partnership produced brochures/posters, a public service announcement, a press conference, an instructional video on traffic control devices, and a slide presentation on traffic control devices. As the team did not have funding for advertising, the initial messages of the campaign were communicated to the extent that that media would carry them free of charge, through televised public service announcements and print media (8). The campaign was driven by their "Know Your Vital Signs" theme, as Figure 3-1 shows.

Figure 3-1. Know Your Vital Signs Logo

The team produced a brochure encouraging drivers to learn, understand, and follow the traffic signs. These brochures were disseminated to an enormous amount of drivers through driver education teachers, student councils, safety program participants, TxDOT public information officers, traveler centers, driver license renewal stations, and civic groups. The brochure and poster (Appendix E), focused on colors and shapes. A second brochure was produced focusing on traffic light configurations, pavement markings, and seven categories of signs.

A public service announcement was produced for television. The announcement encouraged the audience to be familiar with the traffic signs. A press conference was used to "launch" the whole campaign. The news media was provided with the first campaign brochure/poster, the public service announcement, and a summary of the research report (8). Overall, this campaign proved to be successful. According to the report, the campaign was well received by the participating agencies and the general public. The campaign received significant coverage in both the popular media and technical publications. The media's involvement helped to reach many drivers. The clever marketing plan aided in the success.

3.3. Public Information in North Carolina

The North Carolina Department of Transportation's Construction Unit has a public information program called IMPACT (Information Management, Public Affairs, Construction and Traffic Control). The goals of this program are to promote safety in the work zone, inform the public of impacts from construction and provide excellent customer service. This program, or programs like it, could feasibly be the best way to reach the public regarding the five unconventional designs discussed in this report.

The NCDOT's Construction Unit, in conjunction with the Traffic Control Section, the Highway Divisions and the Public Information Office, develops and distributes a wide range of brochures, fliers, press releases, etc. Appendix F displays a few of these examples. The straightforward explanations and diagrams seem to be an effective communication tool.

In addition to this effort, the newspapers typically will contain articles about new traffic patterns, designs or construction. Speaking with traffic columnists at the *News & Observer* and *The Charlotte Observer*, traffic issues are highlighted based on their perceived importance to the driving public. The press releases that NCDOT distributes also bring attention to a variety of new traffic patterns and issues. An estimated 95% of press releases issued by the NCDOT result in stories in a newspaper. As visible as a new arterial is, the chance of a story based on a press release about such a design is excellent. The columnists also address traffic issues based on reader requests.

4. ENFORCEMENT

With respect to enforcement at these unconventional intersections, several traffic engineers from Michigan, New Jersey and North Carolina agree that it is relatively non-existent in the sense of "formal" enforcement. The intersections are, to all intents and purposes, self-enforcing. A driver attempting to make prohibited left turns through one of these intersections will likely encounter the wrath (i.e. honking of horns) of other drivers because he or she will undoubtedly begin to cause a queue for the through movement.

Although the enforcement may theoretically come from other drivers, this is not necessarily a foolproof tactic. For example, in the 1970's there was a jughandle implemented on US 70 in eastern North Carolina. One of the reasons it failed was, with a low volume of traffic, the drivers found it easier to just continue making the left turn at the intersection. Other vehicles were not a strong enough incentive to keep the drivers from making that turn. Therefore, it is wise for a formal enforcement presence to be on site for at least the first few days after the designs go into operation. Enforcement during the AM and PM peak hours would likely be adequate. An increased presence of police officers in the area could help discourage any illegal traffic movements at the intersection.

5. CONCLUSIONS AND RECOMMENDATIONS

Congestion is an ever-present traffic problem on urban and suburban arterials. The conventional solutions to congestion only work so well. Unconventional alternatives provide more ways of addressing the congestion problem. The unconventional alternatives discussed in this report focused on treating left-turns to and from arterials, as they are the cause of many operational problems.

The unconventional alternatives that were considered for this project, because of their potential for widespread implementation in the short term, were the median u-turn, superstreet, jughandle, continuous flow intersection, and bowtie. Because these are different and sometimes new arterial designs, driver confusion is a concern. This report discussed signing plans, enforcement, and public information useful for the implementation of the five designs of interest.

The unnatural vehicle movement matrix illustrated the unnatural and altered movements required to navigate the unconventional designs. In comparison with the number of changed movements needed for the roundabout, the five designs allowed more natural movements. Most of the designs, although requiring some unnatural movements, are signed in a manner that can help the drivers successfully navigate them.

The pedestrian movement matrix illustrated how well the unconventional designs, as well as conventional intersections, accommodate pedestrians. The designs were evaluated by the number of roadways crossed, the number of free-flow crossings, and whether the right-turn movement is free-flowing or controlled. The bowtie and one conventional intersection (with no median and no free right turn) ranked best, followed by the median u-turn and another conventional intersection (with median and no free right turn). The continuous flow intersection ranked last, proving the most difficult for a pedestrian to safely cross.

As shown throughout the report, it is not necessary for traffic engineers to start from the beginning when it comes to signing these designs. The signing systems in use by various states thus far appear effective. Most of the previously mentioned plans would be suitable for use by states wishing to implement these unconventional arterial designs. The signing recommendation for the median u-turn and jughandle designs would be what the states of Michigan and New Jersey, respectively, already have in place. The recommended signing plan for the superstreet is similar to the plan that is in use at the US 301 and Galena Road intersection in Kent County, MD. An addition of a diagrammatic sign on the minor street approach could help drivers better understand how they need to navigate the upcoming intersection. Also, the use of the overhead signs on the minor street approaches (indicating that only right turns are allowed at the intersection) may not be needed. For the continuous flow intersection, the plan used at the MD 210 and MD 228 intersection is recommended with the change of the overhead signs to roadside signs. The bowtie design signing plan illustrated in Appendix B is recommended. Without overhead signs, all plans are in the range of $4000 to $23,000.

An effective public information campaign will enhance a good signing plan. We recommend, upon opening an unconventional design new to an area, that the highway agency use informational brochures such as the ones put out by the NCDOT Impact Team. The brochures should contain basic information about the design and the procedures needed to navigate the design. These brochures should be distributed to driver's license offices, trucking associations, state welcome centers, and driver service organizations (i.e. AAA). Press releases should be used and should result in stories in the local newspaper that could also help inform drivers. Additional enforcement may also be needed upon opening an unconventional design.

6. REFERENCES

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6. Picha, D.L., H.G. Hawkins, Jr., K.N. Womack, et al. Driver Understanding of Alternative Traffic Signs. In *Transportation Research Record 1605*, TRB, National Research Council, Washington, D.C., 1997, pp. 8-16.
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APPENDIX A

SIGNING PLANS AND PICTURES

A.1. MEDIAN U-TURN

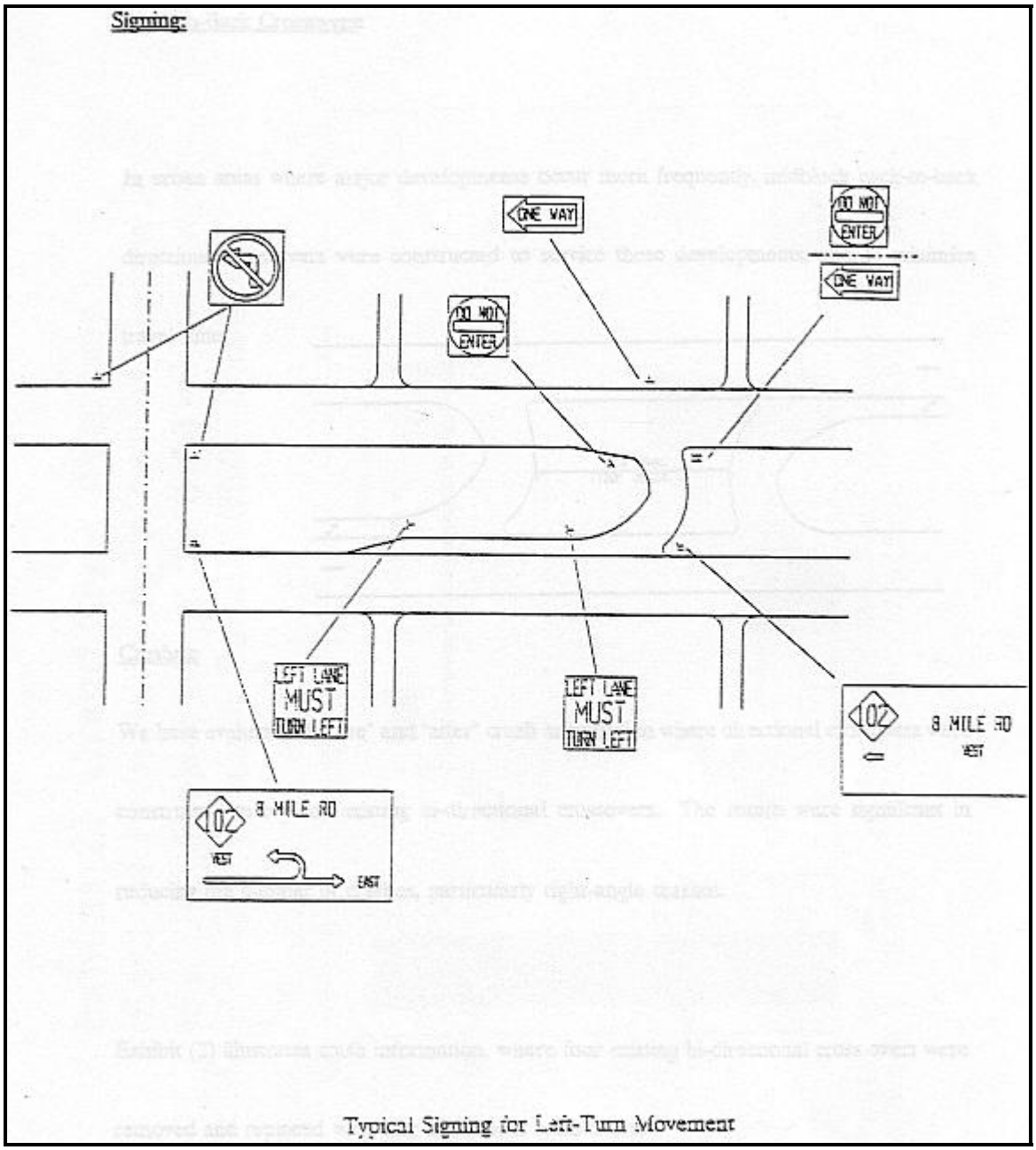


Figure A.1.1 Michigan DOT Median U-Turn Signing Plan (Michigan DOT)

A.2. SUPERSTREET

Figure A.2.1. Superstreet Intersection in Kent County, MD
(Photos by Cipriana D. Thompson)

Figure A.2.2. Superstreet Intersection

Figure A.2.3. Past the Intersection

Figure A.2.4. Past the Intersection

Figure A.2.5. Past the Intersection

Figure A.2.6. Major Street Approach

Figure A.2.7. Minor Street Approach

Figure A.2.8. Sign on Minor Street Approach

A.3. JUGHANDLE

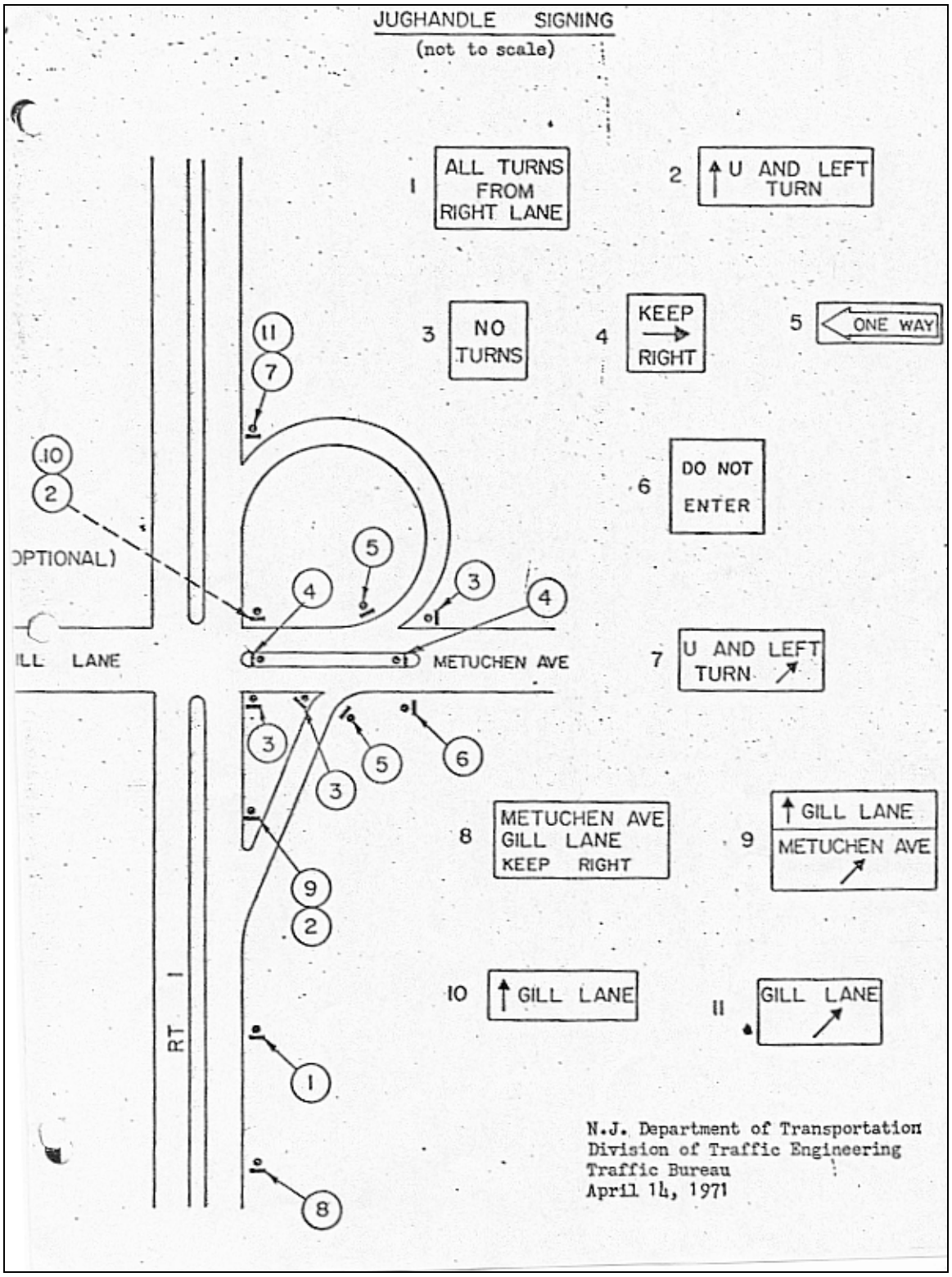


Figure A.3.1. Jughandle Signing Plan 1 (New Jersey DOT)

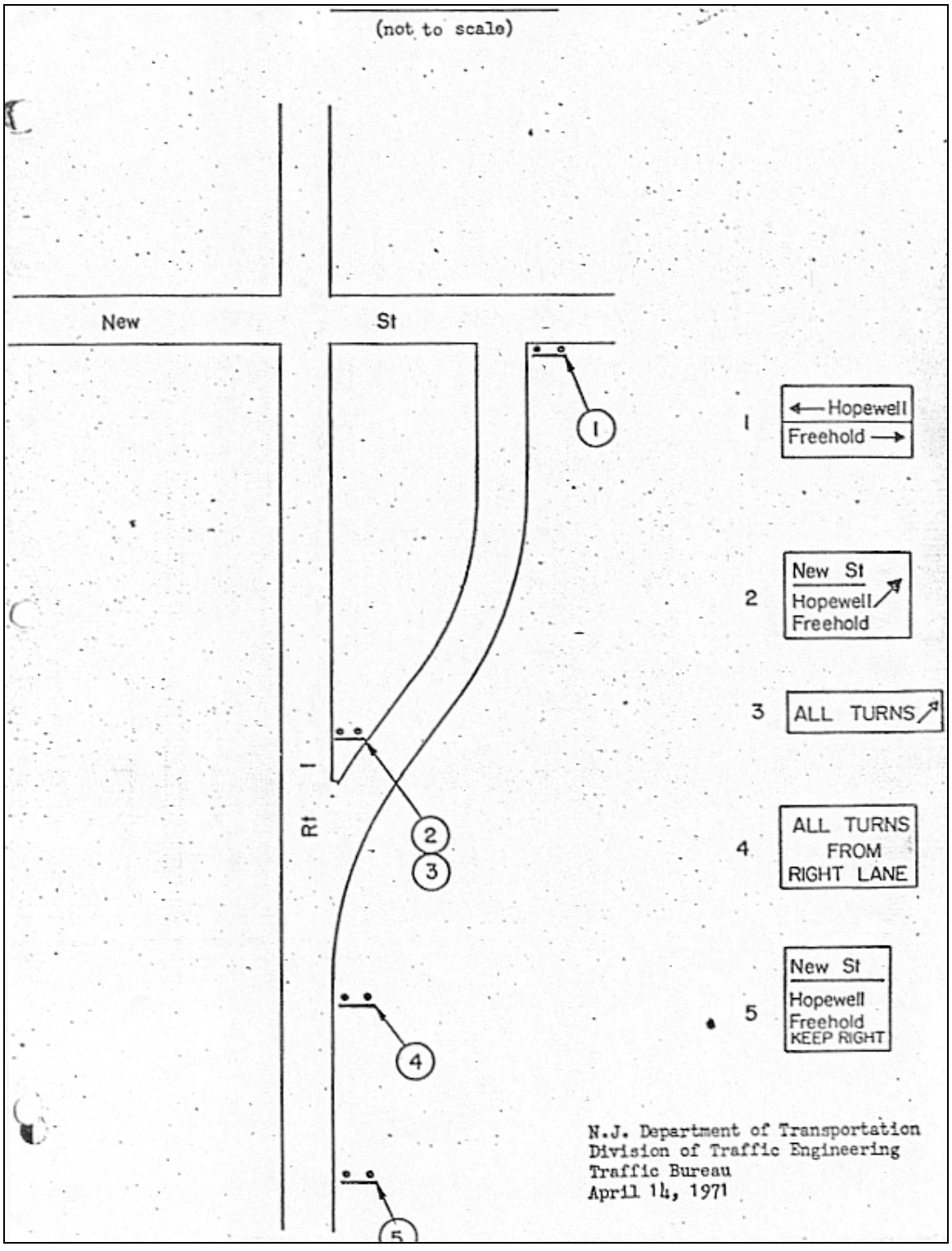


Figure A.3.2. Jughandle Signing Plan 2 (New Jersey DOT)

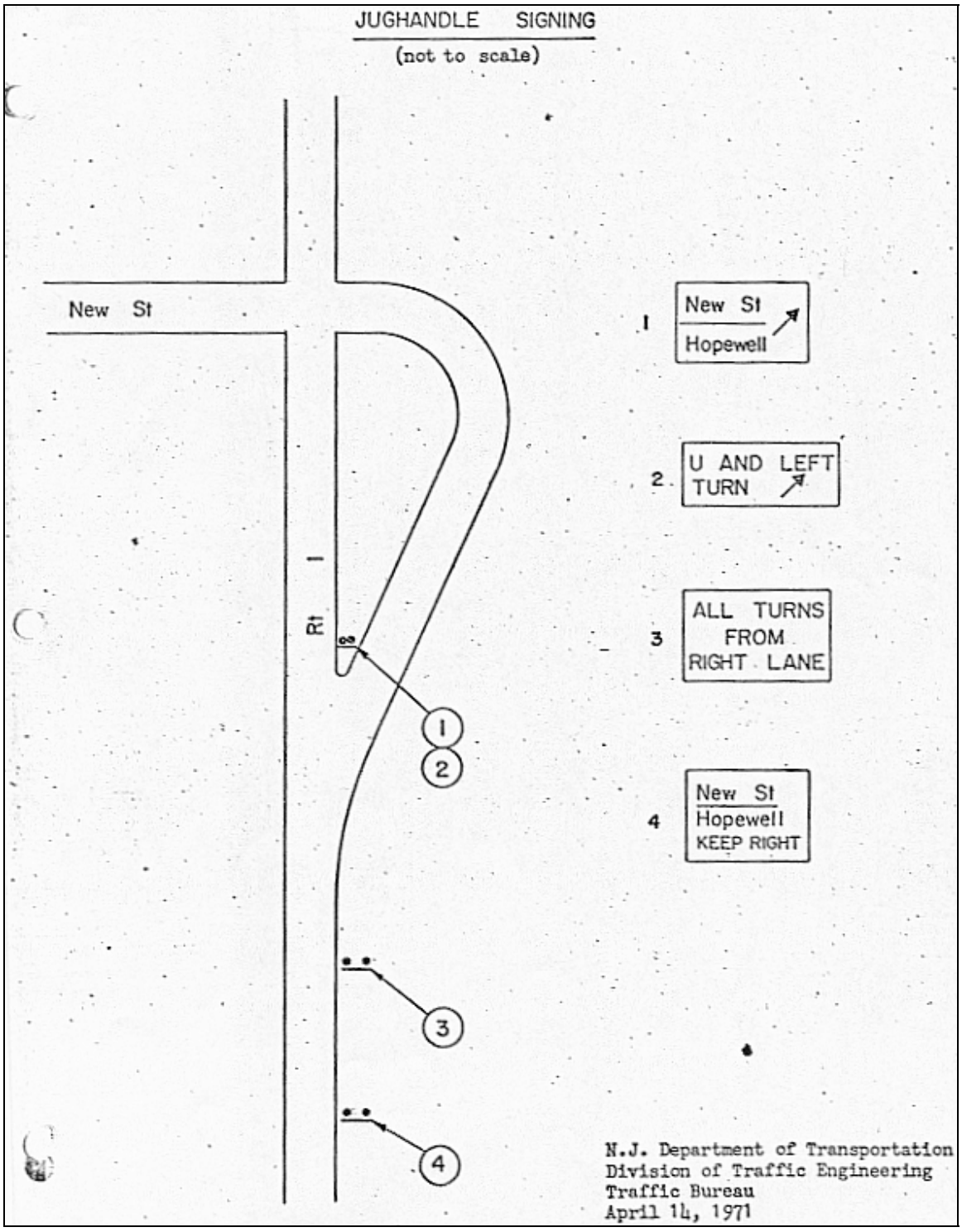


Figure A.3.3. Jughandle Signing Plan 3 (New Jersey DOT)

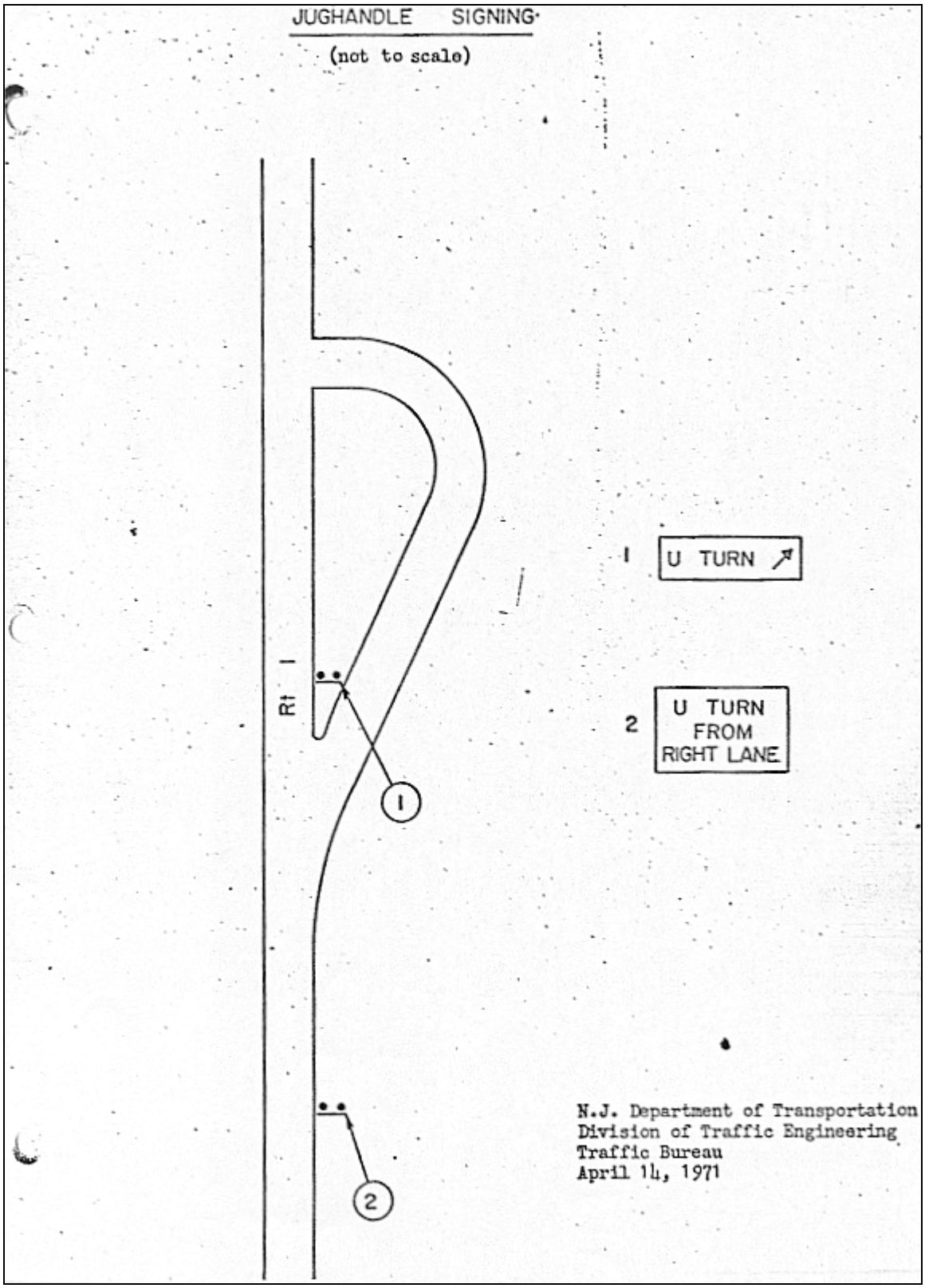


Figure A.3.4. Jughandle Signing Plan 4 (New Jersey DOT)

A.4. CONTINUOUS FLOW INTERSECTION

Figure A.4.1. MD 210 & MD 228, Prince Georges County, MD
(Photos by Cipriana D. Thompson)

Figure A.4.2. MD 210 Southbound – Approaching Intersection

Figure A.4.3. MD 210 Southbound – Approaching Intersection

Figure A.4.4. MD 210 Southbound -- At Intersection

Figure A.4.5. MD 210 Northbound – Approaching Intersection

Figure A.4.6. MD 228 Westbound -- View of Intersection

Figure A.4.7. MD 228 Westbound -- View of Intersection

Figure A.4.8. MD 228 Westbound

Figure A.4.9. MD 228 Westbound

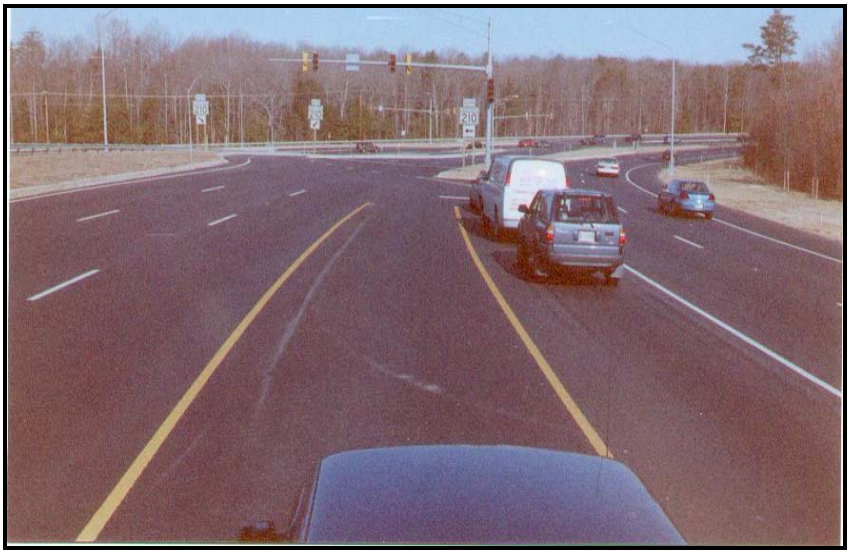


Figure A.4.10. MD 228 Westbound

A.5. BOWTIE

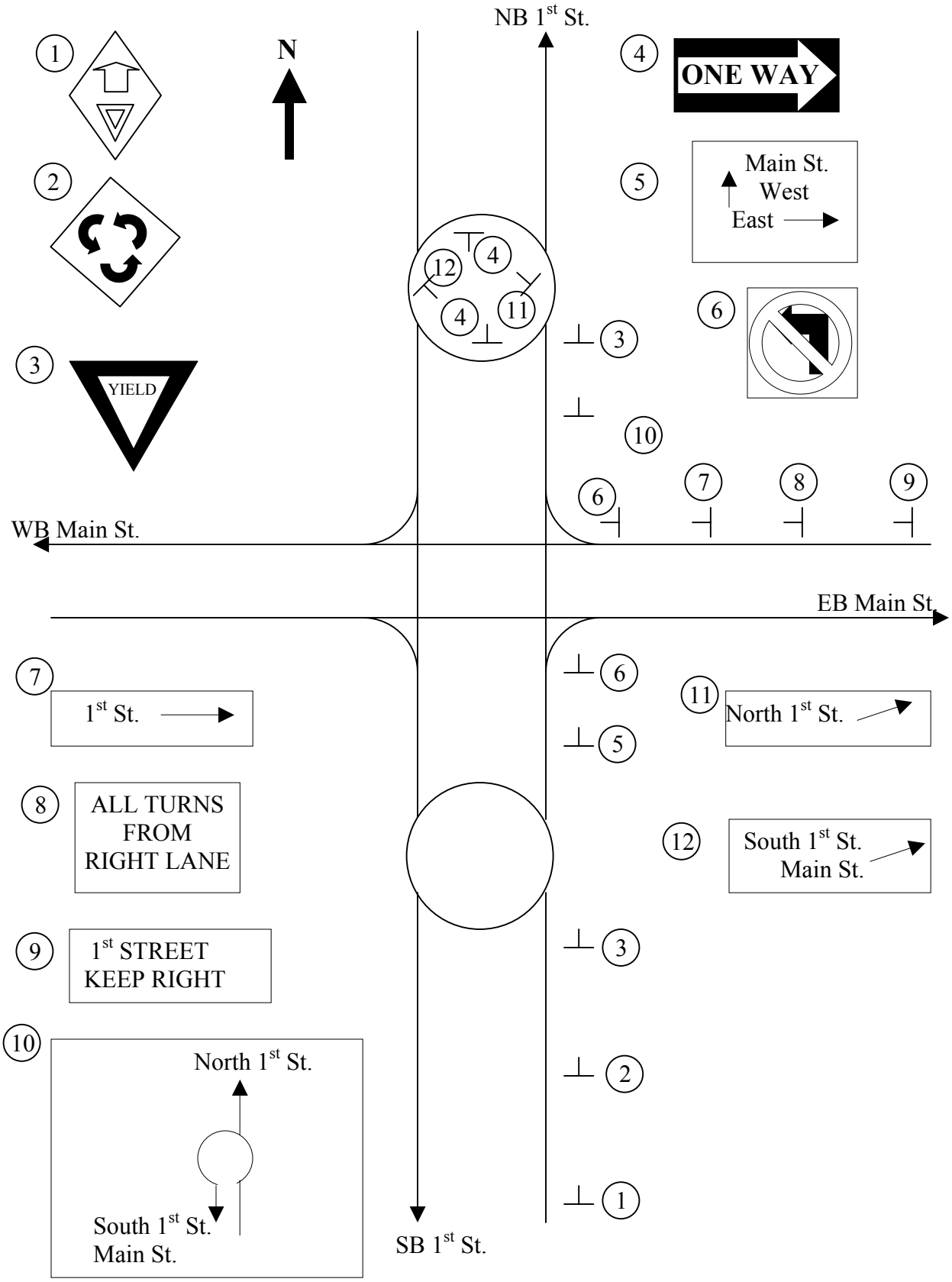


Figure A.5.1 Bowtie Signing Plan (by Research Team)

APPENDIX B

MUTCD STANDARD AND COST DATA FOR SIGNING PLAN

Table B.1 MUTCD Standard and Cost Data

Design	Sign (Quantity)	Standard?	Sign No.	Section	Type	Dimensions (in)	Cost			Total*
							Sign	Mount	Install	
Median U-turn										
	No Left Turn (Symbol) (2)	Yes	R3-2	2B.17	Reg	24x24	$60	$100	$100	$598
	Left Lane Must Turn Left (4)	Yes	R3-7	2B.19	Reg	30x30	$100	$100	$100	$1,380
	Do Not Enter (4)	Yes	R5-1	2B.29	Reg	30x30	$100	$100	$100	$1,380
	One Way (4)	Yes	R6-1L	2B.32	Reg	36x12	$100	$100	$100	$1,380
	Diagrammatic Sign (4)	Yes		2E.19	Guide	72x48	$300	$250	$100	$2,990
										$7,728
Superstreet										
	STOP (2)	Yes	R1-1	2B.04	Reg	30x30	$100	$100	$100	$690
	YIELD (2)	Yes	R1-2	2B.08	Reg	36x36x36	$100	$100	$100	$690
	Left Lane Must Turn Left (4)	Yes	R3-7	2B.19	Reg	30x30	$100	$100	$100	$1,380
	Do Not Enter (2)	Yes	R5-1	2B.29	Reg	30x30	$100	$100	$100	$690
	One Way (4)	Yes	R6-1R	2B.32	Reg	36x12	$100	$100	$100	$1,380
	Right Turn Only (2)	No	n/a	n/a	n/a	24x30	$100	$100	$100	$690
	Stop Ahead (2)	Yes	W3-1	2C.15	Warning	36x36	$100	$100	$100	$690
	U-Turn (w/ diag. Arrow) (2)	No	n/a	n/a	n/a	24x30	$100	$100	$100	$690
	US Route Marker (4)	Yes	M1-4	2D.10/11	Guide	30x24	$100	$100	$100	$1,380
	To Marker (2)	Yes	M4-5	2D.21	Guide	24x12	$80	$100	$100	$644
	Advance Turn Arrow (4)	Yes	M5-1R	2D.25	Guide	21x15	$60	$100	$100	$1,196
	Exit Direction Sign (2)	Yes	*E6-2a*	2E.11	Guide		$300	$250	$100	$1,495
	Right Only at 301 & Stop Ahead* (2)	No	n/a	n/a	n/a		$300	$40,000		$92,690
	**Does not include flashing beacon*									**$104,305**
Jughandle 1 (Reverse)										
	All Turns From Right Lane (2)	No	n/a	n/a	n/a	60x36	$180	$80	$100	$828
	U And Left Turn 1 (4)	No	n/a	n/a	n/a	60x24	$120	$190	$100	$1,886
	No Turns (6)	Yes	R3-3	2B.17	Reg	24x24	$80	$90	$100	$1,863
	Keep Right (4)	Yes	R4-7A	2B.28	Reg	24x30	$100	$100	$100	$1,380
	One Way (4)	Yes	R6-1L	2B.32	Reg	36x12	$100	$100	$100	$1,380
	Do Not Enter (2)	Yes	R5-1	2B.29	Reg	30x30	$100	$100	$100	$690
	U And Left Turn 2 (2)	No	n/a	n/a	n/a	60x24	$120	$190	$100	$943
	Destination Sign/Keep Right (2)	No	n/a	n/a	n/a	Variable	$120	$190	$100	$943
	Destination Sign (2)	Yes	D1-2	2D-34	Guide	Variable	$120	$190	$100	$943
	Destination Sign (4)	Yes	D1-1	2D-34	Guide	Variable	$120	$190	$100	$1,886
										$12,742

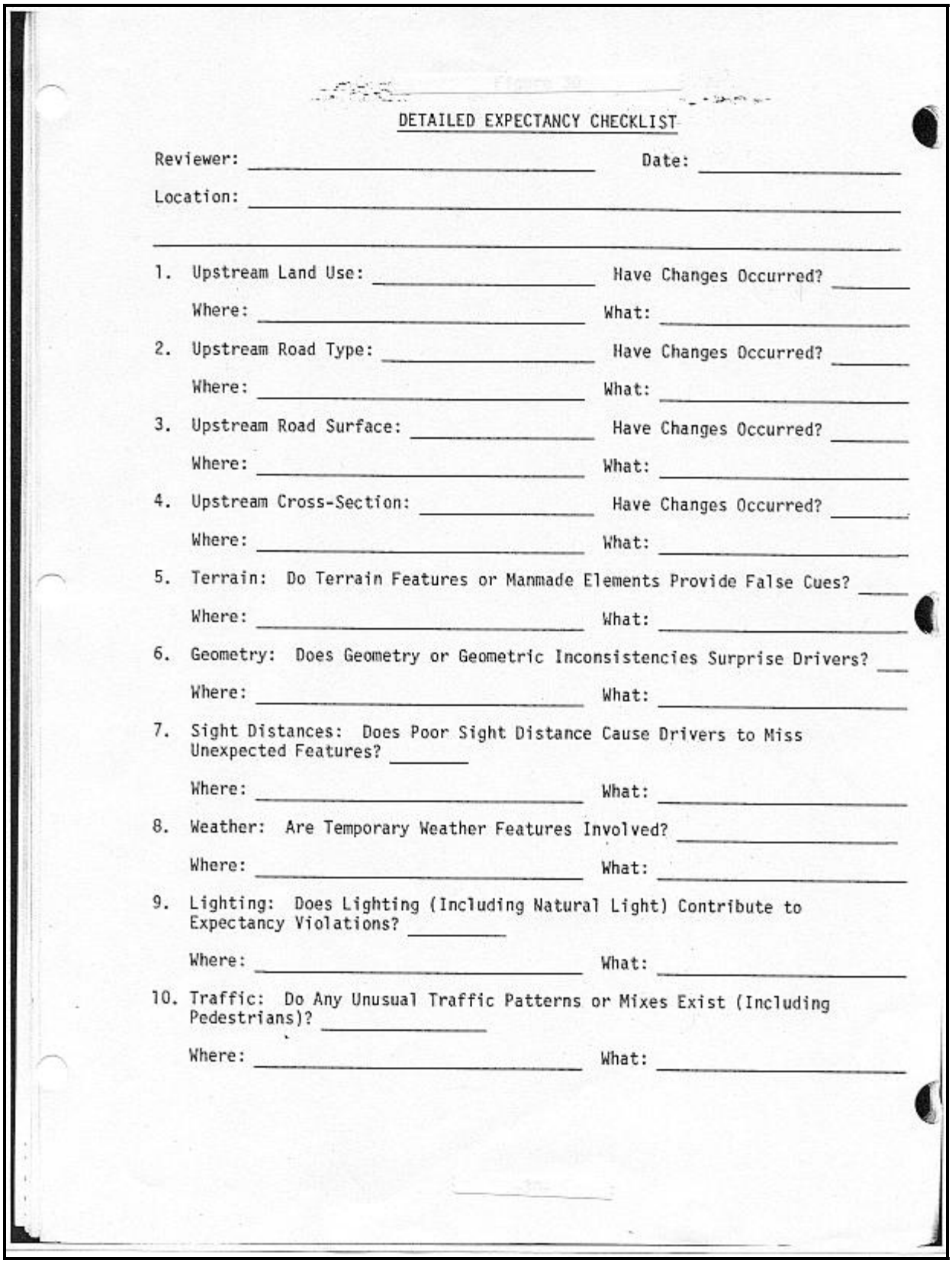
Table B.1 MUTCD Standard and Cost Data cont.

Design	Sign	Standard?	Sign No.	Section	Type	Dimensions (in)	Cost			Total*
							Sign	Mount	Install	
Jughandle 2										
	Destination Sign (6)	Yes	D1-1	2D-34	Guide	Variable	$120	$190	$100	$2,829
	All Turns (2)	No	n/a	n/a	n/a	72x18	$110	$190	$100	$920
	All Turns From Right Lane (2)	No	n/a	n/a	n/a	60x36	$180	$80	$100	$828
										$4,577
CFI										
	No Right Turn (Symbol) (2)	Yes	R3-1	2B.17	Reg	24x24	$80	$90	$100	$621
	No Left Turn (Symbol) (2)	Yes	R3-2	2B.17	Reg	24x24	$60	$100	$100	$598
	Left Lane Must Turn Left (2)	Yes	R3-7	2B.17	Reg	30x30	$100	$100	$100	$690
	One Way (2)	Yes	R6-1L	2B.32	Reg	36x12	$100	$100	$100	$690
	Lane Ends Merge Left (2)	Yes	W9-2	2C.28	Warning	36x36	$100	$100	$100	$690
	Lane Ends Merge Right (2)	Yes	W9-2	2C.28	Warning	36x36	$100	$100	$100	$690
	Lane Reduction (4)	Yes	W4-2	2C.28	Warning	36x36	$100	$100	$100	$1,380
	No Turns (2)	Yes	R3-3	2B.17	Reg	24x24	$80	$90	$100	$621
	Curve (2)	Yes	W1-2R	2C.6	Warning	30x30	$100	$100	$100	$690
	Destination Sign (2)	Yes	D1-1	2D-34	Guide	Variable	$120	$190	$100	$943
	Traffic From Right Does Not Stop (2)	No	n/a	n/a	n/a	30x30	$100	$100	$100	$690
	Cardinal Direction Marker (10)	Yes	M3-1 - M3-4	2D.15	Guide	24x12	$80	$100	$100	$3,220
	Directional Arrow (10)	Yes	M6-1 - M6-3	2D.26	Guide	21x15	$60	$100	$100	$2,990
	Chevron (4)	Yes	W1-8	2C.10	Warning	18x24	$80	$100	$100	$1,288
	Diagrammatic Signs for Split (4)	Yes		2E.20	Guide		$1,200	$40,000		$189,520
										$205,321
Bowtie										
	No Left Turn (Symbol) (4)	Yes	R3-2	2B.17	Reg	24x24	$60	$100	$100	$1,196
	YIELD (4)	Yes	R1-2	2B.08	Reg	36x36x36	$100	$100	$100	$1,380
	All Turns From Right Lane (2)	No	n/a	n/a	n/a	60x36	$180	$80	$100	$828
	Destination Sign (2)	Yes	D1-2	2D-34	Guide	Variable	$120	$190	$100	$943
	Destination Sign (6)	Yes	D1-1	2D-34	Guide	Variable	$120	$190	$100	$2,829
	Yield Ahead (Symbol) (2)	Yes	W3-2a	2C.25	Warning	36x36	$100	$100	$100	$690
	Circular Intersection (2)	Yes	W2-6	2C.34	Warning	36x36	$100	$100	$100	$690
	Diagrammatic Sign (2)	Yes		2E.19	Guide	72x48	$300	$250	$100	$1,495
	One Way (4)	Yes	R6-1R	2B.32	Reg	36x12	$100	$100	$100	$1,380
	Destination Sign/Keep Right (2)	No	n/a	n/a	n/a	Variable	$120	$190	$100	$943
										$12,374

*Total includes 15% mobilization cost and quantity of signs

APPENDIX C

DETAILED EXPECTANCY CHECKLISTS



DETAILED EXPECTANCY CHECKLIST

Reviewer: _____ Date: _____

Location: _____

_____

1. Upstream Land Use: _____ Have Changes Occurred? _____

   Where: _____ What: _____

2. Upstream Road Type: _____ Have Changes Occurred? _____

   Where: _____ What: _____

3. Upstream Road Surface: _____ Have Changes Occurred? _____

   Where: _____ What: _____

4. Upstream Cross-Section: _____ Have Changes Occurred? _____

   Where: _____ What: _____

5. Terrain: Do Terrain Features or Manmade Elements Provide False Cues? _____

   Where: _____ What: _____

6. Geometry: Does Geometry or Geometric Inconsistencies Surprise Drivers? ___

   Where: _____ What: _____

7. Sight Distances: Does Poor Sight Distance Cause Drivers to Miss Unexpected Features? _____

   Where: _____ What: _____

8. Weather: Are Temporary Weather Features Involved? _____

   Where: _____ What: _____

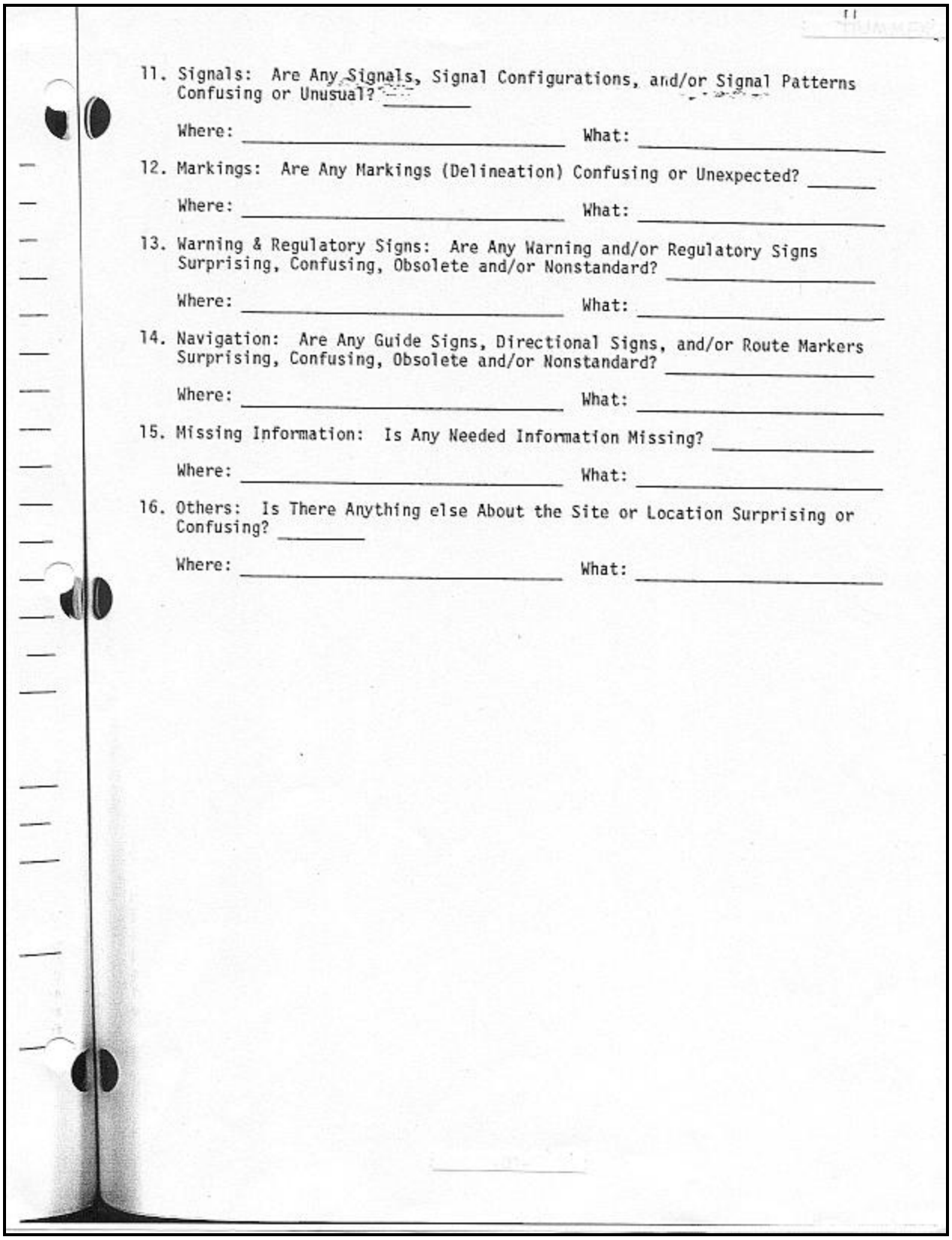
9. Lighting: Does Lighting (Including Natural Light) Contribute to Expectancy Violations? _____

   Where: _____ What: _____

10. Traffic: Do Any Unusual Traffic Patterns or Mixes Exist (Including Pedestrians)? _____

    Where: _____ What: _____

Figure C.1 Blank Expectancy Checklist (Alexander and Lunenfeld)



11. Signals: Are Any Signals, Signal Configurations, and/or Signal Patterns Confusing or Unusual? _____

Where: _____ What: _____

12. Markings: Are Any Markings (Delineation) Confusing or Unexpected? _____

Where: _____ What: _____

13. Warning & Regulatory Signs: Are Any Warning and/or Regulatory Signs Surprising, Confusing, Obsolete and/or Nonstandard? _____

Where: _____ What: _____

14. Navigation: Are Any Guide Signs, Directional Signs, and/or Route Markers Surprising, Confusing, Obsolete and/or Nonstandard? _____

Where: _____ What: _____

15. Missing Information: Is Any Needed Information Missing? _____

Where: _____ What: _____

16. Others: Is There Anything else About the Site or Location Surprising or Confusing? _____

Where: _____ What: _____

Figure C.1 Blank Expectancy Checklist cont.

DETAILED EXPECTANCY CHECKLIST

Reviewer: Hummer Date: 7/17/01

Location: Median U-Turn – Michigan

1. Upstream Land Use: Retail Have Changes Occurred? No
   Where: What:

2. Upstream Road Type: Arterial Have Changes Occurred? No
   Where: What:

3. Upstream Road Surface: OK Have Changes Occurred? No
   Where: What:

4. Upstream Cross-Section: 4-6 lane, 50'-60' median Have Changes Occurred? No
   Where: What:

5. Terrain: Do Terrain Features or Manmade Elements Provide False Cues? No
   Where: What:

6. Geometry: Does Geometry or Geometric Inconsistencies Surprise Drivers? No
   Where: What:

7. Sight Distances: Does Poor Sight Distance Cause Drivers to Miss Unexpected Features? No
   Where: What:

8. Weather: Are Temporary Weather Features Involved? No
   Where: What:

9. Lighting: Does Lighting (Including Natural Light) Contribute to Expectancy Violations? No
   Where: What:

10. Traffic: Do Any Unusual Traffic Patterns or Mixes Exist (Including Pedestrians)? Yes
    Where: At crossovers and between crossover and main intersection
    What: Rerouting left turns to crossovers, weaving

11. Signals: Are Any Signals, Signal Configurations, and/or Signal Patterns Confusing or Unusual? No, simpler
    Where: What:

12. Markings: Are Any Markings (Delineation) Confusing or Unexpected? No
    Where: What:

Figure C.2 Median U-Turn Checklist

13. Warning & Regulatory Signs: Are Any Warning and/or Regulatory Signs Surprising, Confusing, Obsolete and/or Nonstandard? Yes, surprising
    Where: At intersection What: No left turn

14. Navigation: Are Any Guide Signs, Directional Signs, and/or Route Markers Surprising, Confusing, Obsolete and/or Nonstandard? Yes, Nonstandard
    Where: On approach What: Diagrammatic sign

15. Missing Information: Is Any Needed Information Missing? No
    Where: _____ What: _____

16. Others: Is There Anything else About the Site or Location Surprising or Confusing? No
    Where: _____ What: _____

DETAILED EXPECTANCY CHECKLIST

Reviewer: Thompson Date: 7/16/01

Location: Superstreet – US 301 & Galena Rd., Kent County, MD

1. Upstream Land Use: Commercial (open) Have Changes Occurred? No
   Where: What:

2. Upstream Road Type: Divided Highway Have Changes Occurred? No
   Where: What:

3. Upstream Road Surface: OK Have Changes Occurred? No
   Where: What:

4. Upstream Cross-Section: 4 lane, 50'-60' median Have Changes Occurred? No
   Where: What:

5. Terrain: Do Terrain Features or Manmade Elements Provide False Cues? No
   Where: What:

6. Geometry: Does Geometry or Geometric Inconsistencies Surprise Drivers? No
   Where: What:

7. Sight Distances: Does Poor Sight Distance Cause Drivers to Miss Unexpected Features? No
   Where: What:

8. Weather: Are Temporary Weather Features Involved? No
   Where: What:

9. Lighting: Does Lighting (Including Natural Light) Contribute to Expectancy Violations? No
   Where: What:

10. Traffic: Do Any Unusual Traffic Patterns or Mixes Exist (Including Pedestrians)? Yes
    Where: At intersection What: No through or left turn movements allowed from Minor Street

11. Signals: Are Any Signals, Signal Configurations, and/or Signal Patterns Confusing or Unusual? No
    Where: What:

12. Markings: Are Any Markings (Delineation) Confusing or Unexpected? No
    Where: What:

Figure C.3 Superstreet Checklist

13. Warning & Regulatory Signs: Are Any Warning and/or Regulatory Signs Surprising, Confusing, Obsolete and/or Nonstandard? Yes, surprising
    Where: At intersection What: No left turn

14. Navigation: Are Any Guide Signs, Directional Signs, and/or Route Markers Surprising, Confusing, Obsolete and/or Nonstandard? Yes, Nonstandard
    Where: On minor street approach What: Right turn only, Right only at 301

15. Missing Information: Is Any Needed Information Missing? Yes
    Where: On minor street approach What: Diagrammatic sign displaying how to complete through or left movement

16. Others: Is There Anything else About the Site or Location Surprising or Confusing? No
    Where: _____ What: _____

DETAILED EXPECTANCY CHECKLIST

Reviewer: Thompson Date: 7/16/01

Location: Jughandle – New Jersey

1. Upstream Land Use: Commercial Have Changes Occurred? No
   Where: What:

2. Upstream Road Type: Arterial Have Changes Occurred? No
   Where: What:

3. Upstream Road Surface: OK Have Changes Occurred? No
   Where: What:

4. Upstream Cross-Section: 6 lane, Jersey Barrier median Have Changes Occurred? No
   Where: What:

5. Terrain: Do Terrain Features or Manmade Elements Provide False Cues? No
   Where: What:

6. Geometry: Does Geometry or Geometric Inconsistencies Surprise Drivers? No
   Where: What:

7. Sight Distances: Does Poor Sight Distance Cause Drivers to Miss Unexpected Features? No
   Where: What:

8. Weather: Are Temporary Weather Features Involved? No
   Where: What:

9. Lighting: Does Lighting (Including Natural Light) Contribute to Expectancy Violations? No
   Where: What:

10. Traffic: Do Any Unusual Traffic Patterns or Mixes Exist (Including Pedestrians)? Yes
    Where: At intersection What: No through or left turn movements allowed from Minor Street

11. Signals: Are Any Signals, Signal Configurations, and/or Signal Patterns Confusing or Unusual? No
    Where: What:

12. Markings: Are Any Markings (Delineation) Confusing or Unexpected? No
    Where: What:

Figure C.4 Jughandle Checklist

13. Warning & Regulatory Signs: Are Any Warning and/or Regulatory Signs Surprising, Confusing, Obsolete and/or Nonstandard? Yes, surprising
    Where: At intersection What: No left turn

14. Navigation: Are Any Guide Signs, Directional Signs, and/or Route Markers Surprising, Confusing, Obsolete and/or Nonstandard? Yes, Nonstandard
    Where: On minor street approach What: Right turn only, Right only at 301

15. Missing Information: Is Any Needed Information Missing? Yes
    Where: On minor street approach What: Diagrammatic sign displaying how to complete through or left movement

16. Others: Is There Anything else About the Site or Location Surprising or Confusing? No
    Where: _____ What: _____

DETAILED EXPECTANCY CHECKLIST

Reviewer: Thompson Date: 7/16/01

Location: Continuous Flow Intersection – MD 210 & MD 228, Prince Georges Co., MD

1. Upstream Land Use: Residential Have Changes Occurred? Yes
   Where: Downstream What: Commercial

2. Upstream Road Type: Divided Highway Have Changes Occurred? No
   Where: What:

3. Upstream Road Surface: OK Have Changes Occurred? No
   Where: What:

4. Upstream Cross-Section: 4 lane, 40'-50' median Have Changes Occurred? No
   Where: What:

5. Terrain: Do Terrain Features or Manmade Elements Provide False Cues? No
   Where: What:

6. Geometry: Does Geometry or Geometric Inconsistencies Surprise Drivers? No
   Where: What:

7. Sight Distances: Does Poor Sight Distance Cause Drivers to Miss Unexpected Features? No
   Where: What:

8. Weather: Are Temporary Weather Features Involved? No
   Where: What:

9. Lighting: Does Lighting (Including Natural Light) Contribute to Expectancy Violations? No
   Where: What:

10. Traffic: Do Any Unusual Traffic Patterns or Mixes Exist (Including Pedestrians)? Yes
    Where: Prior to intersection What: Minor street – the way the movements split

11. Signals: Are Any Signals, Signal Configurations, and/or Signal Patterns Confusing or Unusual? No
    Where: What:

12. Markings: Are Any Markings (Delineation) Confusing or Unexpected? No
    Where: What:

Figure C.5 Continuous Flow Intersection Checklist

13. Warning & Regulatory Signs: Are Any Warning and/or Regulatory Signs Surprising, Confusing, Obsolete and/or Nonstandard? Yes, nonstandard
    Where: At intersection What: Traffic From Right Does Not Stop

14. Navigation: Are Any Guide Signs, Directional Signs, and/or Route Markers Surprising, Confusing, Obsolete and/or Nonstandard? No
    Where: _____ What: _____

15. Missing Information: Is Any Needed Information Missing? No
    Where: _____ What: _____

16. Others: Is There Anything else About the Site or Location Surprising or Confusing? No
    Where: _____ What: _____

DETAILED EXPECTANCY CHECKLIST

Reviewer: Thompson Date: 7/16/01

Location: Bowtie (Based on Signing Plan)

1. Upstream Land Use: Commercial Have Changes Occurred? No
   Where: What:

2. Upstream Road Type: Undivided Highway Have Changes Occurred? No
   Where: What:

3. Upstream Road Surface: OK Have Changes Occurred? No
   Where: What:

4. Upstream Cross-Section: 4 lane Have Changes Occurred? No
   Where: What:

5. Terrain: Do Terrain Features or Manmade Elements Provide False Cues? No
   Where: What:

6. Geometry: Does Geometry or Geometric Inconsistencies Surprise Drivers? No
   Where: What:

7. Sight Distances: Does Poor Sight Distance Cause Drivers to Miss Unexpected Features? No
   Where: What:

8. Weather: Are Temporary Weather Features Involved? No
   Where: What:

9. Lighting: Does Lighting (Including Natural Light) Contribute to Expectancy Violations? No
   Where: What:

10. Traffic: Do Any Unusual Traffic Patterns or Mixes Exist (Including Pedestrians)? Yes
    Where: At intersection What: No left turns, must use roundabout to on minor street to make left turns

11. Signals: Are Any Signals, Signal Configurations, and/or Signal Patterns Confusing or Unusual? No
    Where: What:

12. Markings: Are Any Markings (Delineation) Confusing or Unexpected? No
    Where: What:

Figure C.6 Bowtie Checklist

13. Warning & Regulatory Signs: Are Any Warning and/or Regulatory Signs Surprising, Confusing, Obsolete and/or Nonstandard? Yes, nonstandard
Where: Prior to intersection What: All Turns from Right Lane, Left Turns Keep Straight

14. Navigation: Are Any Guide Signs, Directional Signs, and/or Route Markers Surprising, Confusing, Obsolete and/or Nonstandard? Yes
Where: Approaching the Intersection What: Diagrammatic Sign

15. Missing Information: Is Any Needed Information Missing? No
Where: _____ What: _____

16. Others: Is There Anything else About the Site or Location Surprising or Confusing? No
Where: _____ What: _____

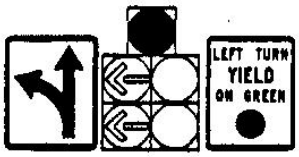
APPENDIX D

PUBLIC INFORMATION BROCHURES

City of San Buenaventura, California

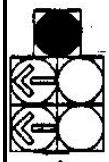
3RD STREET
WESTBOUND AT JACKSON STREET
EASTBOUND AT WASHINGTON STREET

The new "protected/permissive" signal operation to be installed at the intersections of 3rd Street with Jackson and Washington Streets will consist of a basic six step (phase) signal sequence for traffic in the left lane of 3rd Street (westbound to southbound at Jackson and eastbound to northbound at Washington) as indicated below. Although the signal operation will be the same as at 6th and Jackson and 6th and Washington, the allowable traffic movements are somewhat different because of the difference in the lane configurations. Note the additional sign that will be used at these locations.

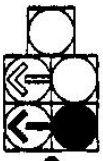


Left lane signal display with signs.

Signal Operation Sequence

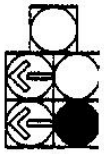


1 Red light. All traffic in this lane must stop. Cross street traffic is proceeding.

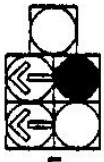


2 Green arrow with green ball. Traffic in the left lane may either turn left or continue straight across the intersection. The green arrow indicates that the left turn is "protected," that is, both the oncoming traffic and cross street traffic are stopped.

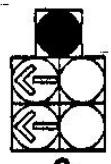
3 Yellow arrow with green ball. The yellow arrow indicates that the "protected" left turn is terminating, and oncoming traffic is about to receive a green light. Traffic in the left lane may continue to go straight across the intersection, but left-turners must now prepare to yield to oncoming traffic.



4 Green ball. Oncoming traffic now has a green light. Traffic in this lane may continue to go straight across the intersection. However, as indicated by the sign, traffic in this lane must now yield to oncoming traffic before turning left.

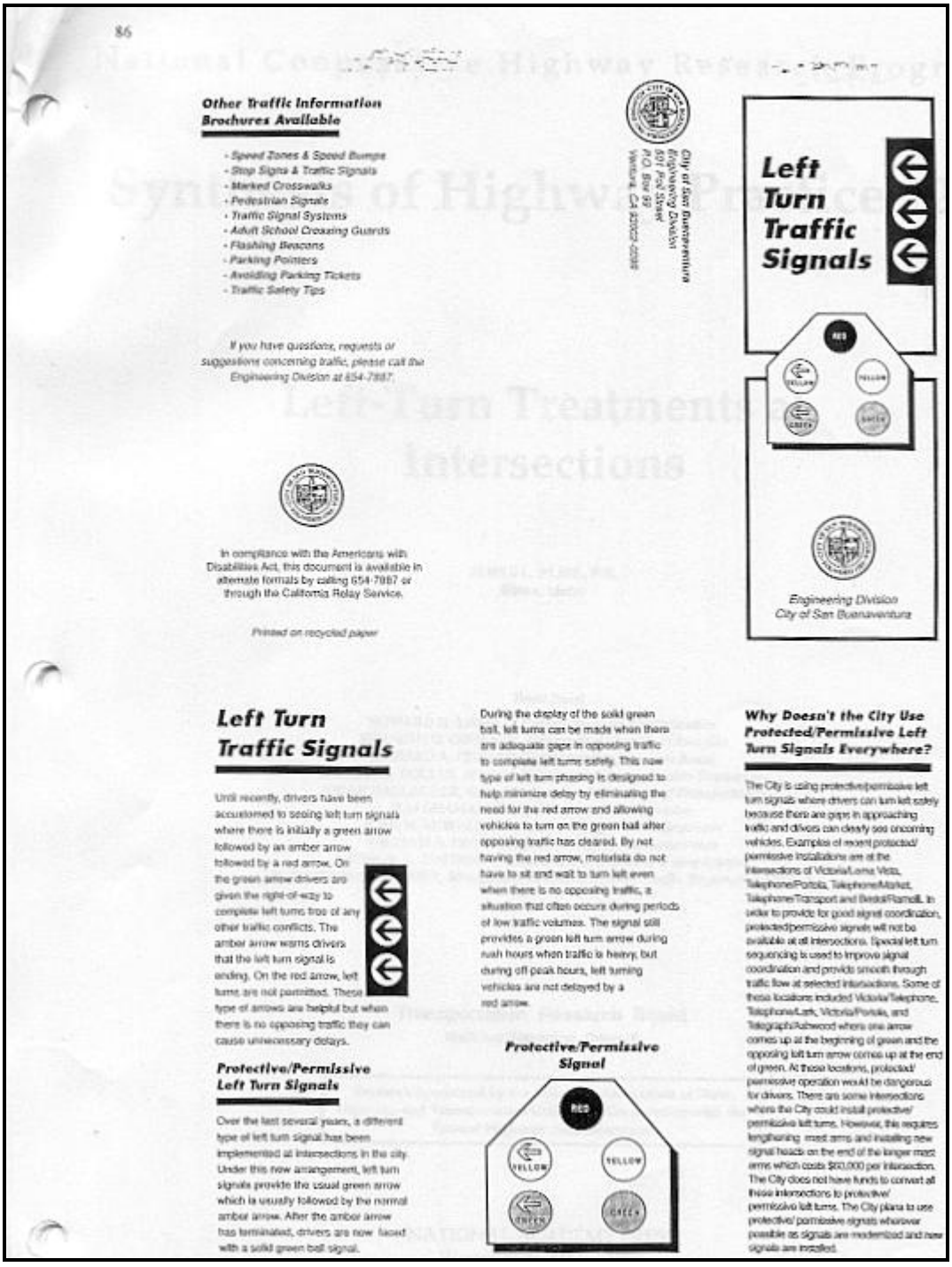


5 Yellow ball. Prepare to stop. The light is about to change to red. Cross street traffic is about to start proceeding.



6 Red light. All traffic in this lane must stop. Cross street traffic is proceeding.

Figure D.1 Protective/Permissive Signal Brochure (Pline)



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Other Traffic Information Brochures Available

- Speed Zones & Speed Bumps
- Stop Signs & Traffic Signals
- Marked Crosswalks
- Pedestrian Signals
- Traffic Signal Systems
- Adult School Crossing Guards
- Flashing Beacons
- Parking Pointers
- Avoiding Parking Tickets
- Traffic Safety Tips

If you have questions, requests or suggestions concerning traffic, please call the Engineering Division at 654-7887.

City of San Buenaventura
Engineering Division
501 Poli Street
P.O. Box 99
Ventura, CA 93002-0099

In compliance with the Americans with Disabilities Act, this document is available in alternate formats by calling 654-7887 or through the California Relay Service.

Printed on recycled paper

Left Turn Traffic Signals

Engineering Division
City of San Buenaventura

Left Turn Traffic Signals

Until recently, drivers have been accustomed to seeing left turn signals where there is initially a green arrow followed by an amber arrow followed by a red arrow. On the green arrow drivers are given the right-of-way to complete left turns free of any other traffic conflicts. The amber arrow warns drivers that the left turn signal is ending. On the red arrow, left turns are not permitted. These type of arrows are helpful but when there is no opposing traffic they can cause unnecessary delays.

Protective/Permissive Left Turn Signals

Over the last several years, a different type of left turn signal has been implemented at intersections in the city. Under this new arrangement, left turn signals provide the usual green arrow which is usually followed by the normal amber arrow. After the amber arrow has terminated, drivers are now faced with a solid green ball signal.

During the display of the solid green ball, left turns can be made when there are adequate gaps in opposing traffic to complete left turns safely. This new type of left turn phasing is designed to help minimize delay by eliminating the need for the red arrow and allowing vehicles to turn on the green ball after opposing traffic has cleared. By not having the red arrow, motorists do not have to sit and wait to turn left even when there is no opposing traffic, a situation that often occurs during periods of low traffic volumes. The signal still provides a green left turn arrow during rush hours when traffic is heavy, but during off peak hours, left turning vehicles are not delayed by a red arrow.

Protective/Permissive Signal

Why Doesn't the City Use Protected/Permissive Left Turn Signals Everywhere?

The City is using protective/permissive left turn signals where drivers can turn left safely because there are gaps in approaching traffic and drivers can clearly see oncoming vehicles. Examples of recent protected/permissive installations are at the intersections of Victoria/Loma Vista, Telephone/Portola, Telephone/Market, Telephone/Transport and Bristol/Ramelli. In order to provide for good signal coordination, protected/permissive signals will not be available at all intersections. Special left turn sequencing is used to improve signal coordination and provide smooth through traffic flow at selected intersections. Some of these locations included Victoria/Telephone, Telephone/Lark, Victoria/Portola, and Telegraph/Ashwood where one arrow comes up at the beginning of green and the opposing left turn arrow comes up at the end of green. At these locations, protected/permissive operation would be dangerous for drivers. There are some intersections where the City could install protective/permissive left turns. However, this requires lengthening mast arms and installing new signal heads on the end of the longer mast arms which costs $60,000 per intersection. The City does not have funds to convert all these intersections to protective/permissive left turns. The City plans to use protective/permissive signals wherever possible as signals are modernized and new signals are installed.

Figure D.2 Left-Turn Traffic Signals Brochure (Pline)

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LEFT-TURN PHASING WARRANTS

NEW YORK CITY

Nationally accepted warrants do not exist to assist traffic engineers in the use of the protected/permissive left-turn phasing technique. For this reason the Bureau of Traffic (N.Y.C.D.O.T.)has developed it's own warrants. The warrants used for approving a left-turn phasing at signalized intersections are based on accident experience and left-turn capacity.

The following two warrants are utilized by the Bureau before recommending the implementation of a Left-Turn phase:

WARRANT 1 (Accident Experience): This Warrant is satisfied when a minimum of 5 related left-turn accidents exist in a 12 month period. If accidents can not be obtained for the latest 12 month period, then accident information for previous periods may be used for the analysis.

WARRANT 2 (Left-Turn Capacity): This warrant is satisfied when for the analyzed direction the left-turn flow rate exceeds the left-turn capacity. The left-turn capacity is the maximum flow rate that may be assigned to the designated phase.

The warrant allows the engineer to analyze approaches with exclusive left-turn bays and approaches with shared left-turn and through vehicles.

The Bureau of Traffic requires the completion of the 5 page "Left-Turn Phasing" warrant study. The study includes the field survey page (geometrics, signal phasing, timing, turning movements, etc.) and the Warrant 1/Warrant 2 calculation pages.

Copies of the study may be obtained by notifying the Bureau of Traffic Operations.

The following definitions are used with the left-turn phasing analysis:

TIPS TRAFFIC INFORMATION PROGRAM SERIES - Revised 1999

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Protected-Only (Exclusive) Left-Turn: The left-turn driver is directed to turn left in a protected manner through the display of a green arrow, and then directed by the display of a circular red to wait for the next traffic signal cycle and its corresponding green arrow.

Permissive Left-Turn: The left-turn driver is not directed to turn left in a protected manner during the circular green in a traffic signal cycle and may only turn left when the gap in the opposing through traffic is adequate to ensure a safe left-turn or turn left at signal's yellow clearance period.

Protected-Permissive (Leading) Left-Turn: The left-turn driver is first directed to turn left in a protected manner through the display of a green arrow, then gets the opportunity to turn permissively when adequate gaps appear in opposing traffic through the display of a circular green.

Permissive-Protected (Lagging) Left-Turn: The left-turn driver is first given the opportunity to turn permissively when adequate gaps appear in opposing traffic through the display of a circular green, then directed to turn left in a protected manner through the display of a green arrow.

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Figure D.3 Left-Turn Phasing Warrants Brochure (Pline)

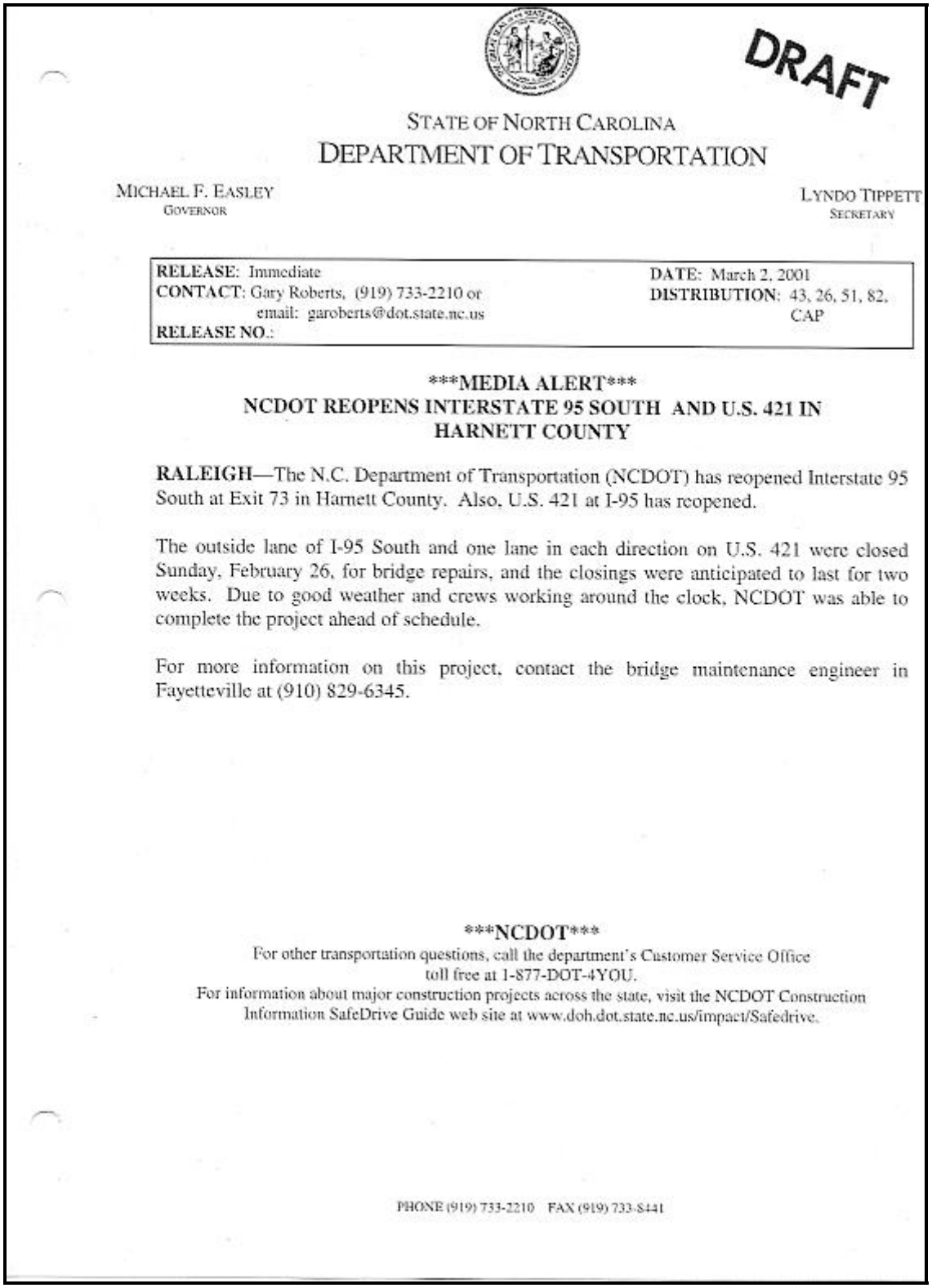
APPENDIX E

TEXAS VITAL SIGNS CAMPAIGN SIGN

Figure E.1. Texas Vital Signs Campaign Sign (Hawkins, Lancaster, Fette, et al.)

APPENDIX F

NCDOT PUBLIC INFORMATION BROCHURES



DRAFT

STATE OF NORTH CAROLINA
DEPARTMENT OF TRANSPORTATION

MICHAEL F. EASLEY
GOVERNOR

LYNDO TIPPETT
SECRETARY

RELEASE: Immediate
CONTACT: Gary Roberts, (919) 733-2210 or
email: garoberts@dot.state.nc.us
RELEASE NO.:

DATE: March 2, 2001
DISTRIBUTION: 43, 26, 51, 82, CAP

*****MEDIA ALERT*****
NCDOT REOPENS INTERSTATE 95 SOUTH AND U.S. 421 IN HARNETT COUNTY

RALEIGH—The N.C. Department of Transportation (NCDOT) has reopened Interstate 95 South at Exit 73 in Harnett County. Also, U.S. 421 at I-95 has reopened.

The outside lane of I-95 South and one lane in each direction on U.S. 421 were closed Sunday, February 26, for bridge repairs, and the closings were anticipated to last for two weeks. Due to good weather and crews working around the clock, NCDOT was able to complete the project ahead of schedule.

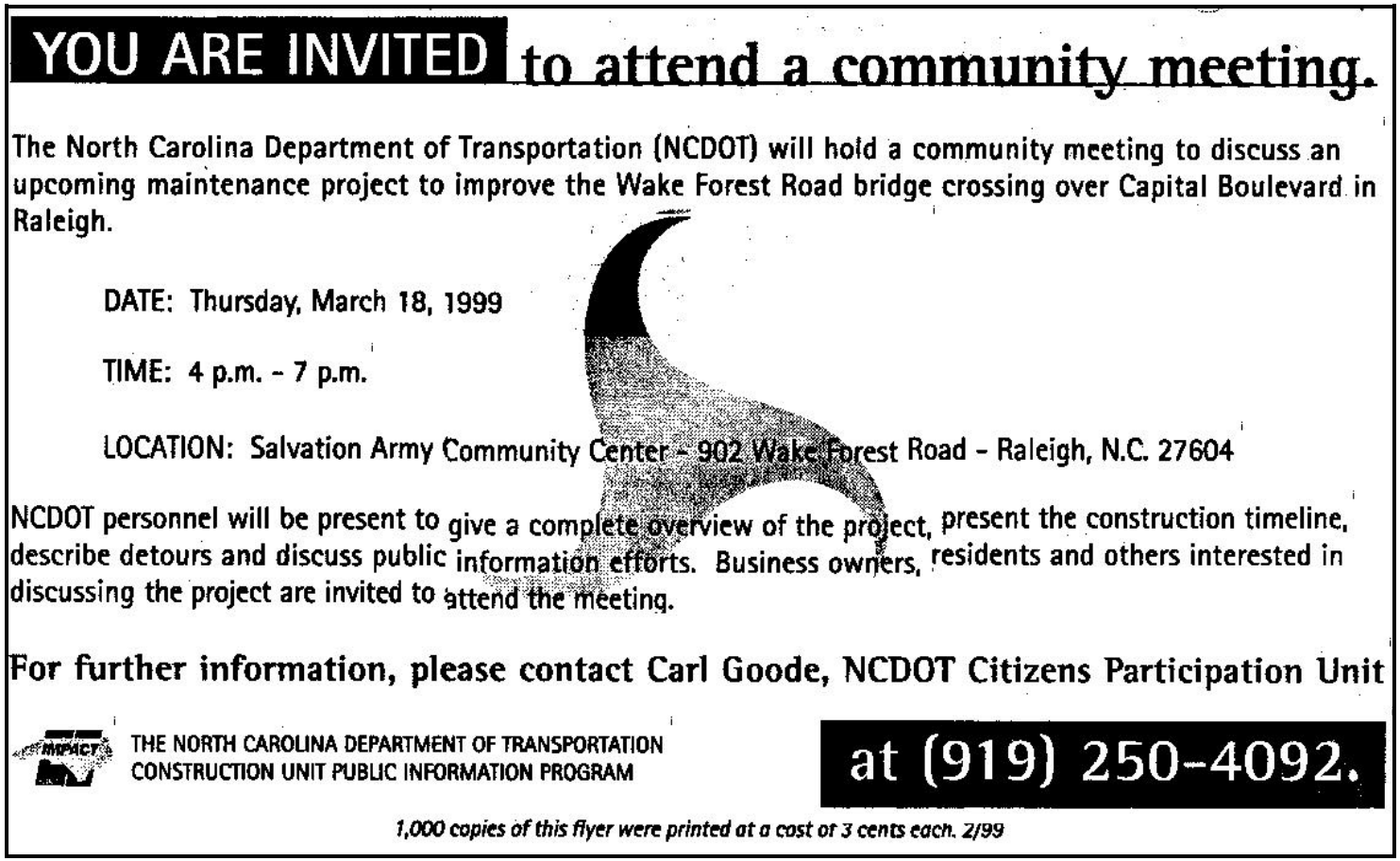
For more information on this project, contact the bridge maintenance engineer in Fayetteville at (910) 829-6345.

*****NCDOT*****
For other transportation questions, call the department's Customer Service Office toll free at 1-877-DOT-4YOU.
For information about major construction projects across the state, visit the NCDOT Construction Information SafeDrive Guide web site at www.doh.dot.state.nc.us/impact/Safedrive.

PHONE (919) 733-2210 FAX (919) 733-8441

Figure F.1 NCDOT News Release (NCDOT)

Figure F.2 Community Meeting Flyer (NCDOT)



YOU ARE INVITED to attend a community meeting.

The North Carolina Department of Transportation (NCDOT) will hold a community meeting to discuss an upcoming maintenance project to improve the Wake Forest Road bridge crossing over Capital Boulevard in Raleigh.

DATE: Thursday, March 18, 1999

TIME: 4 p.m. - 7 p.m.

LOCATION: Salvation Army Community Center - 902 Wake Forest Road - Raleigh, N.C. 27604

NCDOT personnel will be present to give a complete overview of the project, present the construction timeline, describe detours and discuss public information efforts. Business owners, residents and others interested in discussing the project are invited to attend the meeting.

For further information, please contact Carl Goode, NCDOT Citizens Participation Unit

IMPACT

THE NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
CONSTRUCTION UNIT PUBLIC INFORMATION PROGRAM

at (919) 250-4092.

1,000 copies of this flyer were printed at a cost of 3 cents each. 2/99

Figure F.3 Project/Construction Information Flyer (NCDOT)

NCDOT is widening U.S. 29 and adding REVERSIBLE lanes near Lowe's Motor Speedway

The N.C. Department of Transportation (NCDOT) is widening three miles of U.S. 29 to six lanes from Pavilion Boulevard to the Rocky River in Cabarrus County. Morehead Road will be widened to four lanes from U.S. 29 to south of Hudspeth Road.

The department is adding a reversible lane system to accommodate commuter traffic and heavy event traffic at Lowe's Motor Speedway. Overhead directional arrows will be added to allow traffic flow to reverse as needed.

Construction is scheduled to be complete by summer 2001.

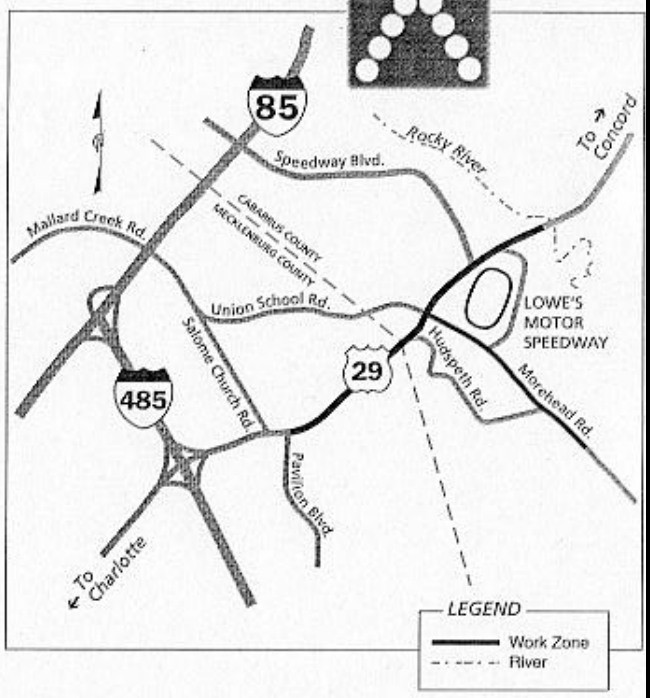
During construction, motorists can expect:

- Traffic to remain in its existing pattern throughout most of construction.
- All lanes will remain open on the following roads from 6:30 a.m. until 9 a.m. and from 4 p.m. until 6 p.m., Monday through Friday and during holidays and special events:
  - U.S. 29
  - Pavilion Boulevard
  - Speedway Boulevard and
  - Morehead Road.

There will be an abundance of construction workers and equipment in this busy work zone.

MOTORISTS AND TRUCKERS SHOULD DRIVE THE POSTED SPEED LIMIT.

For more information on this project, contact the resident engineer in Harrisburg at (704) 455-2958.



North Carolina Department of Transportation
Construction Unit Public Information Program

Recycling is part of NCDOT construction.
For more information, contact the resident engineer.

U-3115

2,000 copies of this flyer were printed at a cost of 3 cents each. 6/99

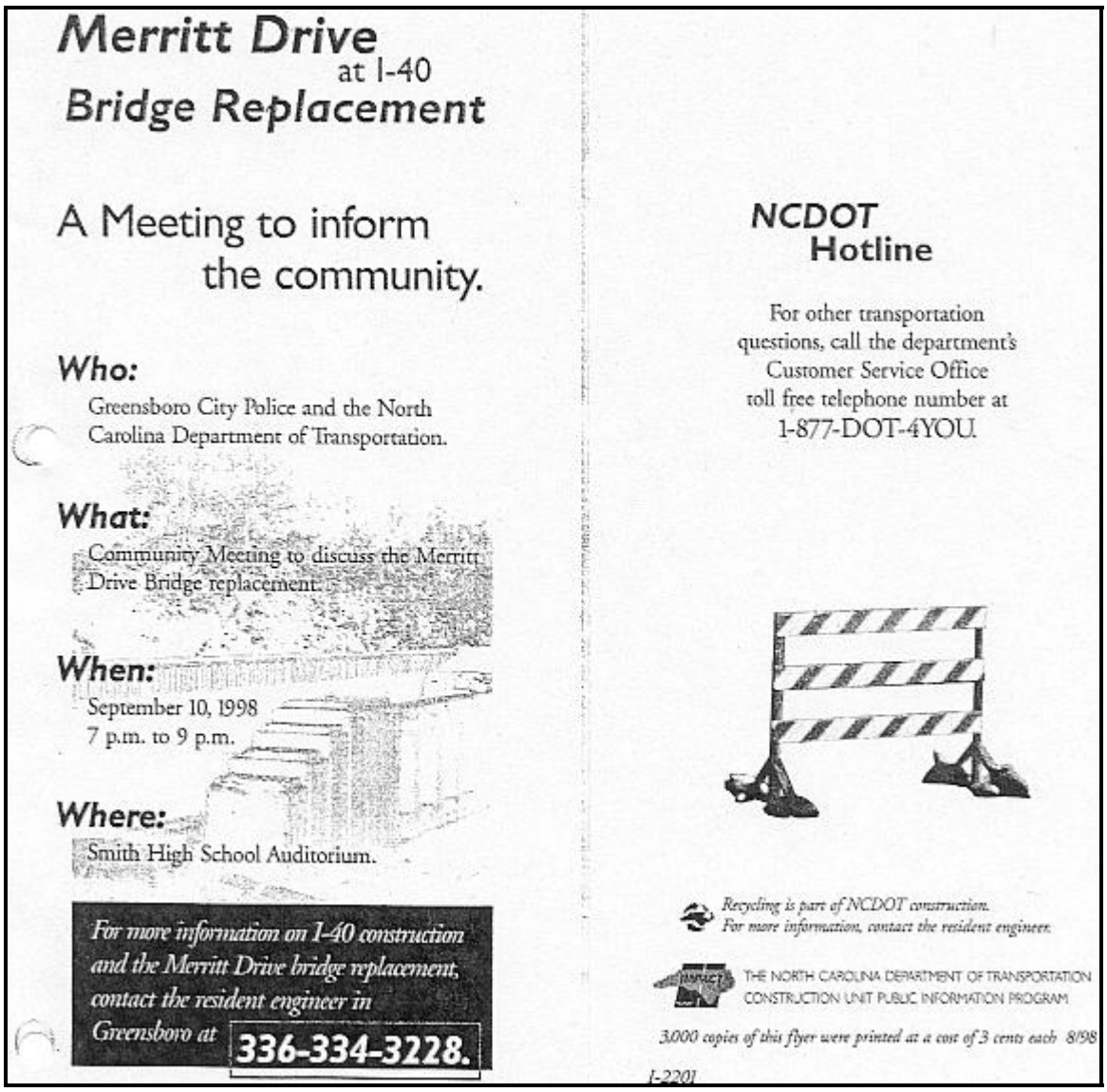


Figure F.4 Community Meeting Door Hanger (NCDOT)

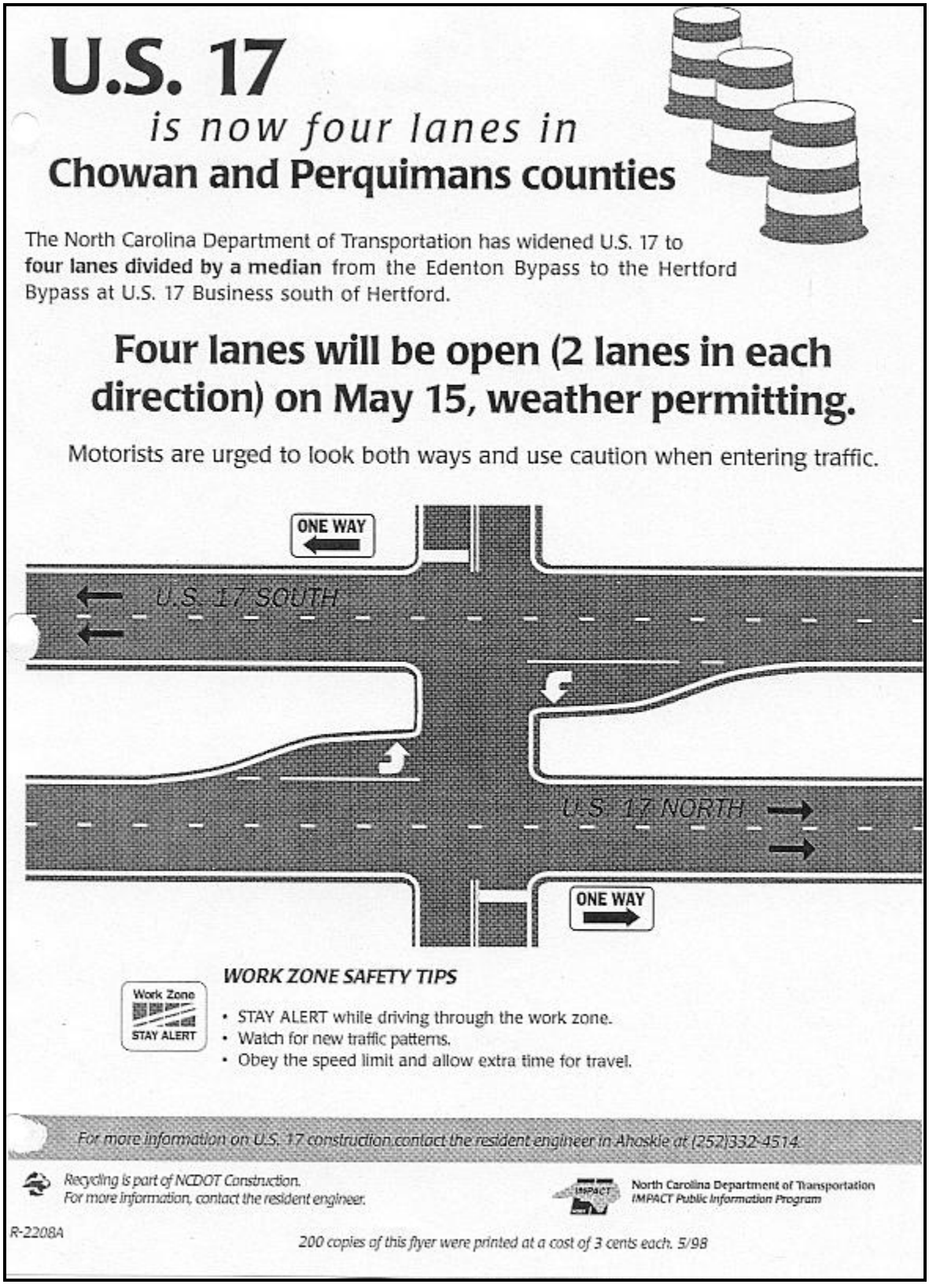
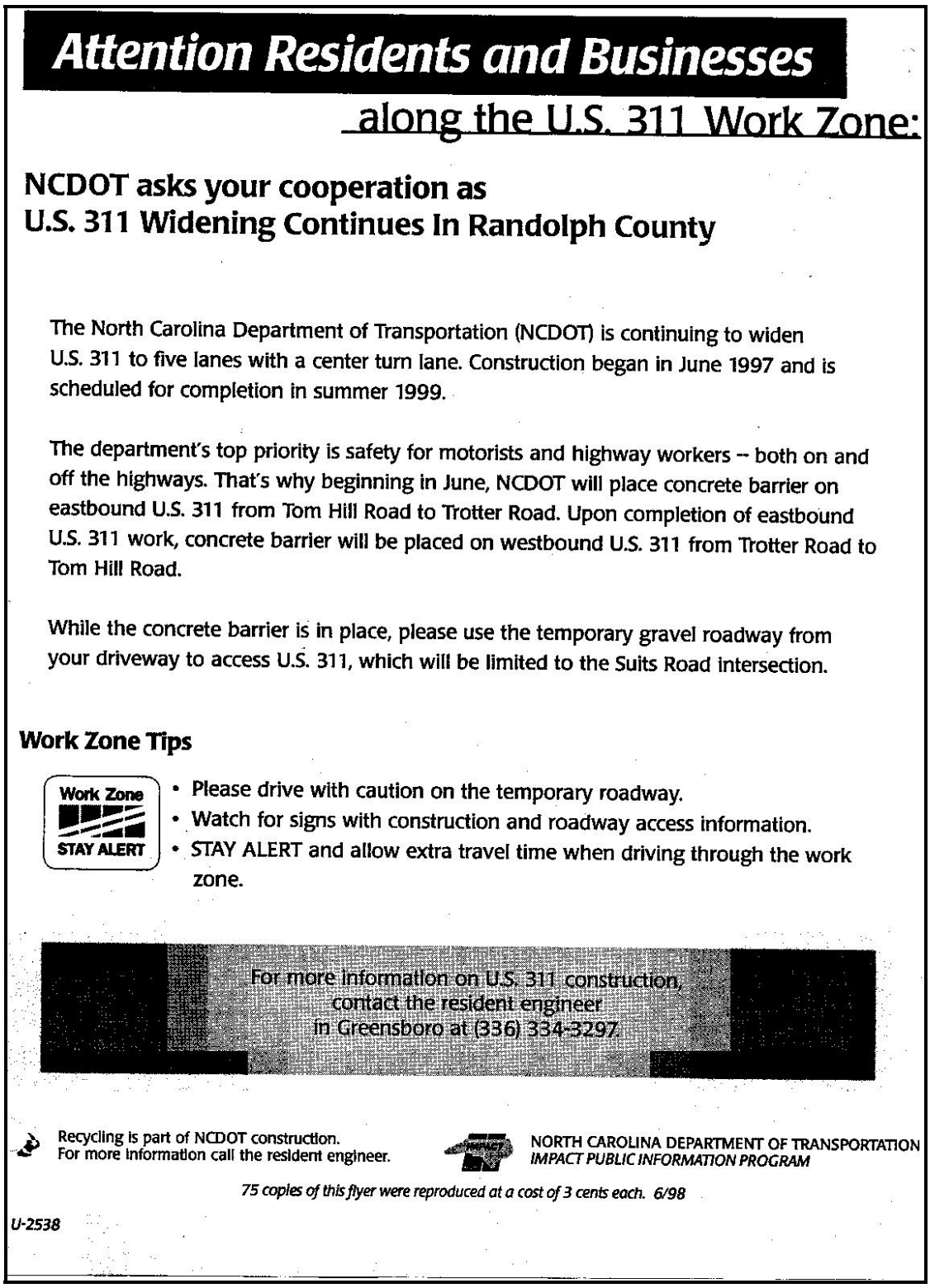


Figure F.5 Road Widening Information Flyer (NCDOT)



Attention Residents and Businesses

along the U.S. 311 Work Zone:

NCDOT asks your cooperation as U.S. 311 Widening Continues In Randolph County

The North Carolina Department of Transportation (NCDOT) is continuing to widen U.S. 311 to five lanes with a center turn lane. Construction began in June 1997 and is scheduled for completion in summer 1999.

The department's top priority is safety for motorists and highway workers -- both on and off the highways. That's why beginning in June, NCDOT will place concrete barrier on eastbound U.S. 311 from Tom Hill Road to Trotter Road. Upon completion of eastbound U.S. 311 work, concrete barrier will be placed on westbound U.S. 311 from Trotter Road to Tom Hill Road.

While the concrete barrier is in place, please use the temporary gravel roadway from your driveway to access U.S. 311, which will be limited to the Suits Road intersection.

Work Zone Tips

Work Zone
STAY ALERT

- Please drive with caution on the temporary roadway.
- Watch for signs with construction and roadway access information.
- STAY ALERT and allow extra travel time when driving through the work zone.

For more information on U.S. 311 construction, contact the resident engineer in Greensboro at (336) 334-3297.

Recycling is part of NCDOT construction. For more information call the resident engineer.

NORTH CAROLINA DEPARTMENT OF TRANSPORTATION
IMPACT PUBLIC INFORMATION PROGRAM

75 copies of this flyer were reproduced at a cost of 3 cents each. 6/98

U-2538

Figure F.6 Resident and Business Information Flyer (NCDOT)

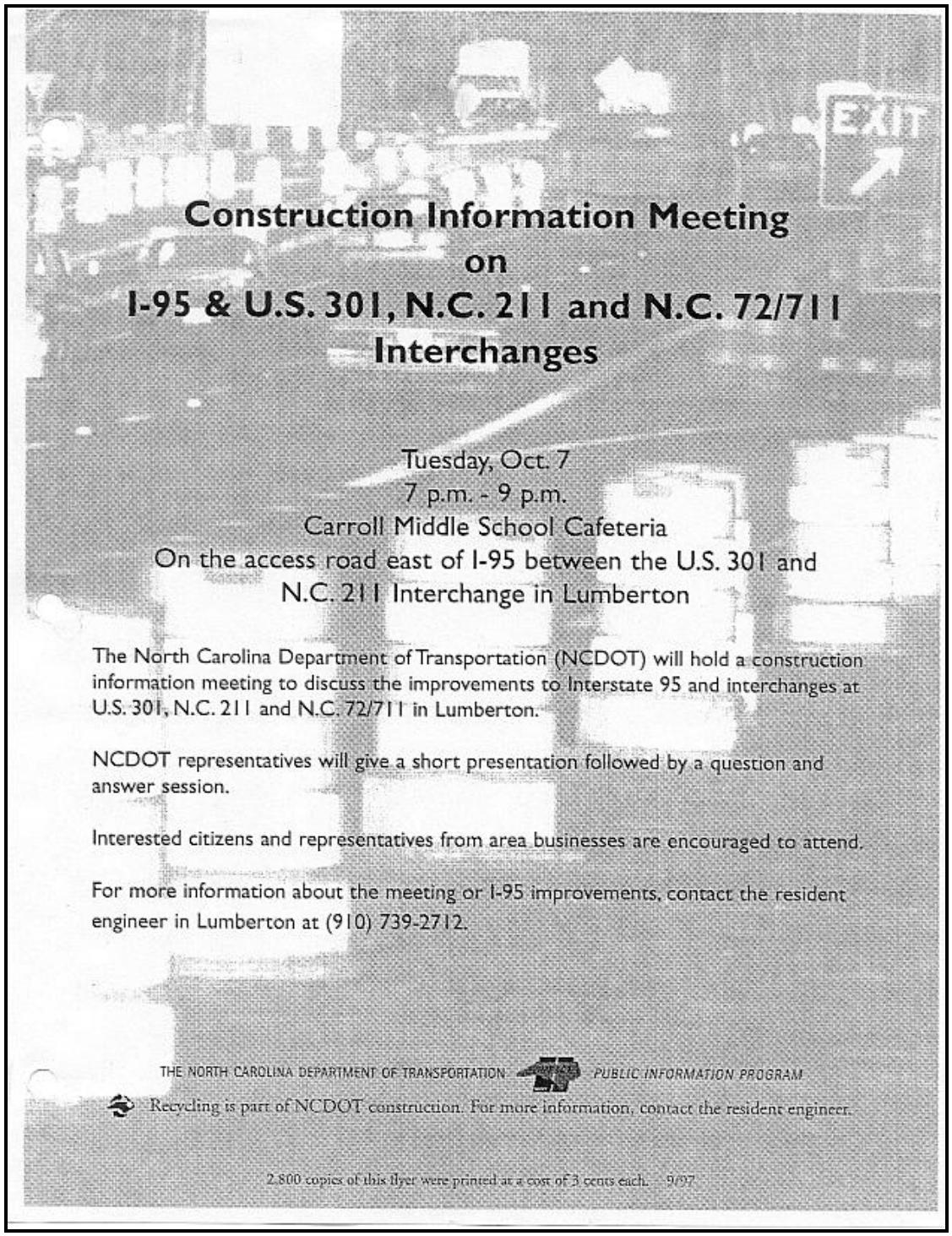


Figure F.7 Construction Information Meeting Flyer (NCDOT)