OPEN ROAD TOLLING SIGNING STUDIES

John Benda
General Manager of Maintenance and Traffic, Illinois State Toll Highway Authority
2700 Ogden Avenue, Downers Grove, Illinois 60515, USA, email: jbenda@getipass.com

Jeff Hochmuth
Principal ITS Engineer, Wilbur Smith Associates, 801 Warrenville Road, Suite 260
Lisle, Illinois 60532, USA, email: jhochmuth@wilbursmith.com

Raghu Kowshik
Transportation Project Manager, Wilbur Smith Associates, 801 Warrenville Road, Suite 260
Lisle, Illinois 60532, USA, email: rkowshik@wilbursmith.com

Laszlo Medgyesy
Senior Transportation Analyst, Wilbur Smith Associates, 801 Warrenville Road, Suite 260
Lisle, Illinois 60532, USA, email: lmedgyesy@wilbursmith.com

Submitted to the 3rd International Conference on Road Safety and Simulation,
September 14-16, 2011, Indianapolis, Indiana, USA

ABSTRACT

In 2004, the Illinois Tollway embarked on an ambitious plan, Open Roads for a Faster Future, to modernize and rebuild virtually the entire system and improve its efficiency. All 20 mainline toll plazas were converted to Open Road Tolling (ORT) within 24 months. The shift to ORT represented a major policy change, presenting significant challenges in educating motorists and conveying relevant information as they approached toll plazas. It quickly became apparent that motorists were having problems navigating the new plaza configurations.

In 2006, the Illinois Tollway requested permission from the Federal Highway Administration (FHWA) to experiment with advance toll plaza signs. First, a low cost laboratory simulation study was conducted to examine the signing using a small sample group. The simulation was designed to evaluate the effectiveness of six alternative advance ORT sign designs under four lighting conditions (daytime, nighttime, overcast, and dawn/dusk), diagrammatic and text-only sign designs, as well as multiple background sign colors. The results were mixed; while the group tended to prefer a certain sign, they often responded better in the simulator to another sign. The laboratory study was followed by a field study which installed variations of the signs at four plazas over several months in 2007. Video data was analyzed in addition to conducting accident analyses.

The results of both studies and recommendations for ORT signing are presented. These results were incorporated into comments on proposed revisions to the Manual on Uniform Traffic Control Devices (MUTCD) addressing toll plaza traffic control devices.

INTRODUCTION

Toll plazas have been designed and constructed in the United States without the benefit of national design standards, often resulting in driver confusion and inefficient vehicle throughput. As a result, toll plaza designs have evolved over time with design elements and practices varying from agency to agency. Standards are often dictated by either legacy toll plaza design practices or variations of historical designs that incorporate enhancements to correct deficiencies.

Toll plaza operations and the accompanying traffic control devices used to facilitate their operation have also varied widely from agency to agency. Schaufler (1997) compiled the first comprehensive state of the practice in toll plaza design. Toll plaza signing practices were found to vary widely across the country with little consistency and uniformity in messages, color, and placement of signs. The next major effort on toll plaza signing was conducted by Stammer and McDonald (2000). This study provided design guidelines for uniform, national toll plaza signing using an expert panel of toll plaza design professionals. However, national standards have been slow to materialize.

Traffic control devices in the United States are regulated by the Federal Highway Administration's (FHWA) *Manual on Uniform Traffic Control Devices for Streets and Highways* (MUTCD). From its inception through its 2003 Edition, the MUTCD did not address traffic control devices for toll plazas. Recognizing this gap, the FHWA sponsored a study to compile the state of the practice on traffic control strategies for toll plazas (Federal Highway Administration, 2006). While the study compiled toll agency operational and design practices, recommendations for toll plaza signing were limited to signing frequency, spacing, and functional needs, rather than detailed assessment of the specific colors, message, and design of the toll signage itself.

Subsequently, the FHWA published a Notice of Proposed Amendments (NPA) to the MUTCD that proposed national standards for toll plaza signing, pavement markings, and other traffic control devices for toll facilities (Federal Highway Administration, 2008). The study described in this paper preceded the NPA and focused on advance toll plaza signs. The application of the NPA to the results of this study are illustrated at the end of the paper.

The Illinois Tollway has been in existence for over 50 years, and has strived to be on the cutting edge among toll agencies with respect to customer service, adoption of new technologies, and providing a premium service to its patrons. The Illinois Tollway is entirely user-fee supported and receives no federal or state funding for its design, construction, or operations. Initial experiments with electronic toll collection (ETC) began in the early 1990's. The Illinois Tollway's ETC system operates under the brand name "I-PASS." Initially, only a few ETC lanes were installed at selected toll plazas, with only approximately 40,000 transponders in circulation. By the late 1990's, the Illinois Tollway had installed I-PASS ETC lanes at all toll plazas. The next steps were to create dedicated I-PASS lanes at the plaza, followed by Express I-PASS lanes at some plazas. The result was a significant increase in transponder use by Illinois Tollway patrons, with I-PASS transactions accounting for approximately 40 to 45 percent of all toll transactions in 2004.

In 2004, the Illinois Tollway embarked on a Congestion Relief Plan (CRP), Open Roads for a Faster Future. This plan included modernizing and rebuilding virtually the entire Illinois Tollway system, to create a safer and more efficient transportation system for its customers. As part of the CRP, all twenty mainline toll plazas were converted to Open Road Tolling (ORT) within twenty-four months. To fund the CRP, the Illinois Tollway issued bonds and adjusted its toll rates for the first time in almost 25 years. A differential toll was adopted, whereby passenger vehicles using I-PASS experienced no change in their toll rate, while cash paying passenger vehicle tolls doubled from their previous rate. Commercial vehicle toll rates were raised to better reflect their true wear and tear on the pavement and the associated maintenance. The short term result of the toll rate changes was a sharp increase in I-PASS participation rates, with average daily I-PASS usage exceeding 65 percent and over 1 million transponders in circulation.

The conversion of all twenty mainline plazas to ORT required a rethinking of how to communicate the new mode of toll plaza operations to the motorists. While the Illinois Tollway did previously have five Express I-PASS lane toll plazas that permitted ETC users to travel through the plaza at highway speeds, the significant increase in I-PASS usage, new I-PASS users, and new toll plaza configurations required an intensive public education campaign. In addition, since cash paying vehicles were now required to exit the roadway to pay their toll and then merge back with mainline traffic, effective advance signing to guide drivers into the appropriate lanes was critical to efficient plaza operations.

ORT Signing Challenges and Initial Efforts

The CRP's aggressive design and construction schedule afforded little time for the design and evaluation of toll plaza advance signing. Additionally, it was recognized that this was a new paradigm for the Illinois Tollway. Considerable effort was put into planning overall plaza operations. In particular, the following challenges in conveying information to motorists were considered:

- Guiding cash-paying patrons to exit from the mainline to pay their toll as the new ORT plaza configuration no longer required I-PASS patrons to slow down or change lanes - unfamiliar or inattentive drivers may not recognize that they are approaching a toll plaza;

- Conveying to unfamiliar drivers that they will reenter the roadway after paying a cash toll;

- Informing unfamiliar/infrequent Illinois Tollway users of the types of payment (electronic – I-PASS and cash) available at the toll plaza, and guiding them into the appropriate lane on the approach to the plaza;

- Informing patrons of interchanges downstream of the toll plaza that are only accessible through the conventional (non-ORT) toll plaza lanes;

- Orienting drivers ahead of the toll plazas to minimize the amount of weaving and lane changing; and,

- Informing cash-paying patrons that they need to come to a stop to pay a cash toll, while simultaneously informing I-PASS drivers of non-stop dedicated I-PASS lanes.

To address these challenges, a new signing scheme was developed for ORT plazas. Within the limited framework of a few overhead signs, the Illinois Tollway needed to communicate the ORT concept to motorists and allow them to take appropriate action. In the fall of 2005, the Illinois Tollway held a series of engineering review meetings and focus groups to design advance signing for the new ORT plazas. While a few highway-speed Express lanes plazas existed on the Illinois Tollway system, the ORT concept was completely new to most motorists.

Although the Illinois Tollway conducted considerable outreach prior to ORT construction, the rapid change in toll plaza operation had a significant impact on motorists. The problem was exacerbated because many ORT lanes opened to traffic while the roadway was still undergoing considerable construction. Motorists had to contend with both new ORT signs and roadwork signs. It quickly became apparent that motorists were having difficulty understanding the new plaza configuration and which lane they had to be in to pay their toll. Initially, an increase in traffic crashes and driver confusion at ORT plazas was observed, which was attributed to the new configuration. This prompted the Illinois Tollway to seek additional study and refinement of the existing ORT signs.

The Illinois Tollway conducted further research via an Internet-based survey of I-PASS users. After some minor field modifications to the ORT signing, it was apparent that a more rigorous approach was required to determine the most appropriate signing.

In considering the next steps, the Illinois Tollway conducted a quick Internet-based survey of existing I-PASS patrons in May 2006. Alternative ORT signs were developed, ranging from minor reconfiguration of the signing to new diagrammatic signs. Links to the survey were provided in electronic newsletters emailed to I-PASS customers. The survey solicited respondents' feedback on four signs, the existing advance ORT toll plaza signs and three alternatives, resulting in over a thousand responses. Survey respondents heavily favored the existing signs. Based on these results, the Illinois Tollway concluded that occasional users required better signing and information, rather than regular commuters. Additional investigation was required to address how best to serve customers.

Development of Study Plan

In order to address ORT signing as comprehensively as possible, the Illinois Tollway initiated a formal engineering study to collect and analyze data that would lead to a sound design. The study was conducted by the Illinois Tollway's traffic engineering consultant, Wilbur Smith Associates.

In June 2006, the Illinois Tollway requested formal approval from the FHWA to experiment with advance signing concepts at ORT plazas. A detailed test plan was developed, and the FHWA granted the Illinois Tollway approval to experiment in August 2006. As part of its' Request to Experiment, the Illinois Tollway agreed to conduct the study in two phases: (1) a laboratory-based simulation study; and, (2) a field test that would install test signs at selected toll plazas.

Since prior focus group studies covered a wide variety of subjects, including the color and shape of the I-PASS logo, it was decided to focus the laboratory and field study on advance signing for the ORT plazas. The primary intent of the laboratory phase of the study was to determine if any of the proposed test signs did not warrant further investigation.

The second phase consisted of a field test in which experimental signs were fabricated and installed on sign trusses in advance of four ORT toll plazas on the Illinois Tollway. This phase would allow direct measurement of effectiveness under actual field conditions. In addition, while prior focus groups and the laboratory study both collected user responses through surveys, they were limited to a small sample of users in a controlled setting. The field study would collect responses to the candidate signs from a much wider audience under actual driving conditions, and allow direct observation of motorist behavior.

LABORATORY STUDY

The purpose of the laboratory study was to obtain scientific data, relatively quickly and inexpensively, to guide the field study. Two partners were recruited to help with this effort: (1) the Electronic Visualization Lab (EVL) at the University of Illinois at Chicago to develop a driving simulation incorporating test signs within a 6 week period; and, (2) the Blackstone Group, a market research firm, to recruit test subjects and host the laboratory test.

Literature Review

In developing the experimental approach for this study, prior laboratory studies of roadway signing were reviewed. Two notable studies influenced the design of the present study:

1. Golembiewski et al (2004). *Traffic Control Devices Pooled Fund Study: Traffic Control Devices at Transponder-Controlled Tollbooth Lanes*. This study used the FHWA Turner Fairbanks Highway Research Center's Sign Simulator to display signs to participants at simulated distances, beginning at 13,500 feet and then slowly "zooming" the signs towards the participants. The detection distance, where subjects indicated when they could first see the sign; the guidance legibility distance, when they could read the guidance information; and, the pictograph legibility distance, when they could read the pictograph, were recorded for each sign.

2. Pisano, P. (June 1992). "Developing a Standard Approach for Testing New Traffic Control Signs", *Public Roads*. This study, conducted by the FHWA's Office of Safety and Traffic Operations, recommended assessing sign effectiveness through the measurement of:

    - Conspicuity – how well a sign is noticed on the roadway;
    - Sign Comprehension – how well the sign's meaning is communicated to the driver; and,
    - Sign Recognition – how easily the sign's contents are identified by drivers.

The study developed a standard methodology to test signs in the laboratory, using a slide projector and timers. Subjects were seated in front of a rear projection screen and images of a sign were shown to the subject. The subject was instructed to advance to the next image as soon as they could identify all the elements of the sign, and the response time was recorded. The time the subject took to identify the sign was considered the recognition time. Comprehension analysis, where the correctness of the response was recorded when the subject was asked to voice their interpretation of the meaning of the sign was also conducted.

Measures of Sign Effectiveness

Based on the above studies, the following Measures of Effectiveness (MOEs) were adopted for this study:

- Recognition Distance – Sign recognition does not require the test subject to understand the sign, but simply to distinguish its contents. The recognition distance is the distance at which subjects can identify the letters of the text and other graphical elements on the sign.

- Comprehension Time – Once the test subject has recognized the sign's contents, the sign comprehension time is the time required for the subject to understand the sign's meaning. This time can be measured by asking test subjects to indicate when they recognize the sign's contents (start of sign comprehension time) and again when they have understood its contents.

Laboratory Study Design

EVL developed a driving simulation program for the laboratory study in which test subjects drove on a simulated highway, which included ORT toll plaza advance signing and the toll plaza itself. The program was designed to be able to project any of the seven test signs on two overhead trusses, and simulate four lighting conditions: daytime, nighttime, dawn and overcast conditions. The physical simulation setup consisted of a personal computer with a high-end graphics card and two high-resolution 30-inch LCD display screens at a combined resolution of 5120x1600 pixels, to allow a visual acuity of 20/28. The system was controlled with a forced-feedback steering wheel, to recreate the sensation of driving. The simulation software was developed using Electro, a virtual-reality prototyping environment developed in house by EVL. The simulated roadway was straight (so as to not introduce other factors) and other vehicles were added ahead of the test car in light traffic conditions. The test driver was able to change lanes freely without risk of hitting another vehicle. All vehicles were kept at a nearly constant 60 mph throughout the test.

Forty eight test subjects were recruited for the laboratory study. A variety of socioeconomic groups were sought, with the main factor being they were not regular users of the Illinois Tollway system. Of the forty eight test subjects, 8 were professional drivers (e.g., limo drivers, truck drivers, etc.) and the remainder passenger vehicle drivers. Each subject was paid a stipend for their time.

Characteristics of Test Subjects

Forty passenger car drivers were recruited for the study, based on three primary criteria: (1) driver age, with adequate representation in three age groupings – 18-24, 25-54 and 55 years or older; (2) familiarity – the primary focus was on infrequent Illinois Tollway users with less familiarity with the ORT plazas; and, (3) I-PASS usage – the primary focus was on cash-paying patrons rather than I-PASS users.

In addition, eight commercial drivers were recruited for the study. Commercial trucks, and large trucks in particular, represent an important segment of the driving population on the Illinois Tollway. The size and weight of large trucks significantly reduces their maneuverability. Further, commercial truck drivers typically drive through many states, with a wider exposure to toll agencies in general. Therefore, including truck drivers in the study would provide the opportunity to evaluate the effectiveness of the test signs, and understand the concerns of this segment of the driving population.

While the recruitment of passenger car drivers was to be conducted as randomly as possible, it was recognized that obtaining a truly random sample of commercial truck drivers was very difficult to achieve, as this was a much smaller subgroup of the driving population. All test subjects were required to be licensed drivers, which was confirmed prior to the test. In addition, commercial drivers were required to show their commercial drivers license (CDL).

<u>Age of Test Subjects</u>

Table 1 presents the age distribution of the test subjects.

Table 1 Age distribution of test subjects

Passenger Car Drivers		
Age Range	Number	Percentage
18 -24	9	22.5%
25 - 34	7	17.5%
35 - 54	11	27.5%
55 and over	13	32.5%
Total	40	100.0%

Commercial Drivers		
Age Range	Number	Percentage
36 - 40	2	25.0%
41 - 45	2	25.0%
46 - 50	1	12.5%
51 - 55	3	37.5%
Total	8	100.0%

Approximately 45 percent of passenger car drivers were between 25 and 54 years, with almost a quarter of the subjects below 25 years of age. A large proportion of the passenger car drivers (32.5 percent) recruited were 55 years or older, matching the intended selection criteria of the study.

Age was not considered a primary criterion in recruiting commercial drivers for this study. The age distribution of truck drivers was much tighter than passenger car drivers, with no truck drivers over 55 years.

<u>Driving Experience</u>

Table 2 presents the length of driving experience for both passenger car and commercial drivers.

Table 2 Length of driving experience of test subjects

	Type of Vehicle Driven			
	Passenger Car		Commercial Vehicle	
Driving Experience	Number	Percentage	Number	Percentage
Less than 1 year	1	2.5%	0	0.0%
1 to 5 years	5	12.5%	3	37.5%
More than 5 years	34	85.0%	5	62.5%
Total	40	100.0%	8	100.0%

Test subjects were predominantly comprised of experienced drivers with only one passenger car driver having held a license for less than a year, and none of the commercial drivers having a CDL for less than a year. Six of the eight commercial drivers possessed an Illinois CDL, with the other two from Indiana and Arkansas, respectively.

Of the six commercial truck drivers who provided a response, five were employed by a company, while one was an independent driver. Of the six respondents, three noted that they drove a five-axle truck, two drove a four-axle truck and one drove a two-axle truck. Two participants did not indicate what type of truck they drove.

<u>Frequency of Tollway and I-PASS Usage</u>

Table 3 summarizes subjects' usage of the Illinois Tollway. Of the passenger car drivers, approximately 70 % drove the Illinois Tollway once per week or less, with 50 percent using the Tollway less than once a week on average. Approximately 63 percent of the commercial drivers drove the Illinois Tollway less than once a week on average.

Of the passenger car drivers, 37.5 percent were I-PASS users, with about 47 percent of these drivers using the Illinois Tollway infrequently, once a week or less on average. Among non I-PASS passenger car drivers, approximately 84 percent drove the Tollway once a week or less, on average. Commercial truck drivers were split evenly among I-PASS/EzPASS and non I-PASS users, with 50 percent or more in each group using the Tollway infrequently (on average once a week or less). One truck driver reported having an EzPASS, which is accepted on the Illinois Tollway.

Table 3 Frequency of Tollway use and I-PASS usage

Passenger Car Drivers						
	All Subjects		I-PASS Users		Non I-PASS Users	
Frequency of Tollway Use	Number	Percentage	Number	Percentage	Number	Percentage
Never	3	8%	-	0%	3	12%
Less than once a month	7	18%	-	0%	7	28%
1 to 3 times a month	7	18%	4	27%	3	12%
Less than once a week	3	8%	-	0%	3	12%
1 trip a week	8	20%	3	20%	5	20%
2 trips a week	3	8%	2	13%	1	4%
3 to 5 trips a week	4	10%	2	13%	2	8%
6 or more trips a week	5	13%	4	27%	1	4%
Total	40	100%	15	100%	25	100%

Commercial Vehicle Drivers						
	All Subjects		I-PASS Users		Non I-PASS Users	
Frequency of Tollway Use	Number	Percentage	Number	Percentage	Number	Percentage
Never	1	3%	1	25%	-	0%
Less than once a month	-	0%	-	0%	-	0%
1 to 3 times a month	4	10%	2	50%	2	50%
Less than once a week	-	0%	-	0%	-	0%
1 trip a week	-	0%	-	0%	-	0%
2 trips a week	1	3%	-	0%	1	25%
3 to 5 trips a week	2	5%	1	25%	1	25%
6 or more trips a week	-	0%	-	0%	-	0%
Total	8	20%	4	100%	4	100%

Native Language

Test subjects were asked which language was most spoken at home. All of the eight commercial truck drivers responded that they spoke English at home, while only two of the passenger car drivers noted that they spoke a language other than English at home. Of these two passenger car drivers, one noted Spanish as the primary language, while the other indicated "Other Language" without specifying the language.

Education

Table 4 presents the highest level of education completed by passenger car drivers and commercial drivers. Among all subjects, the minimum education level was high school.

Table 4 Education Level

Passenger Car Drivers		
Education Level	Number	Percentage
High School	9	22.5%
Some College	13	32.5%
College	8	20.0%
Graduate Studies	10	25.0%
Total	40	100.0%

Commercial Drivers		
Education Level	Number	Percentage
High School	4	50.0%
Some College	3	37.5%
Technical College	1	12.5%
Total	8	100.0%

Visual Acuity

Three questions were asked pertaining to visual acuity: whether the subjects were color blind, if they wore prescription glasses or contact lenses to drive or to read.

Only 1 of the 40 passenger car drivers responded that they were color blind, while none of the commercial truck drivers indicated they were color blind. 15 of the 40 (37.5 percent) passenger car drivers indicated that they wore prescription glasses or contact lenses while driving, with 25 percent (2 of the 8) commercial drivers using prescription glasses or contact lenses for driving. 50 percent (or 20 out of the 40) of passenger car drivers reported using prescription glasses or contacts while reading, with 9 subjects noting use of prescription eyewear while both driving and reading. Two commercial drivers reported using prescription eyewear for reading, with only one reporting its use for both driving and reading.

Familiarity With Technology

Since the laboratory simulation test used a personal computer and was similar to a video game, subjects were asked two questions pertaining to their usage of technology: whether they had played a video game within the prior three months, and whether they owned a personal computer.

Approximately half of the passenger car drivers (53 percent) and commercial drivers (50 percent) had played a video game in the prior three months. The overwhelming majority of passenger car (80 percent) and commercial drivers (75 percent) owned a personal computer.

Test Setup

Test subjects used a large-scale driving simulator to "drive" through an ORT Plaza. Each test subject drove the simulated two-mile roadway 12 times. With a two minute run time for each simulation, this resulted in approximately 30 minutes of simulation runs. The evaluation team felt this was the maximum time a test subject could drive the simulation before introducing other factors. Each time they were exposed to one of seven different experimental signs, and one of four different lighting conditions: daylight, overcast, nighttime and dawn/dusk. During each simulation "run" test subjects were asked to pause the simulation when they could recognize the sign's contents ("Recognition Distance"), and restart the simulation when they had understood the sign's message ("Comprehension Time"). The Recognition Distance and Comprehension Time were automatically recorded for each test run, together with the identifiers for the test signs and lighting conditions. Additionally, the simulation was able to constantly measure the location of the vehicle relative to the simulated centerline of the lane the test vehicle was in. With this information, lane changes could be tracked.

Figure 1 illustrates the seven candidate signs tested in the simulation. Signs were selected to evaluate the impact of using diagrammatic versus text-only signs, different background sign colors and pictographs to convey the configuration of an upcoming ORT toll plaza. In addition, two versions of the toll plaza pictograph sign were tested, one scaled to a standard 10 foot tall sign panel and the other to a 12 foot tall panel. These two versions were included due to the concern that drivers may not be able to distinguish the toll plaza pictograph on the smaller sign. Two background colors of the 12-foot tall pictograph sign were tested. All other test signs simulated a 10-foot tall sign. All test signs simulated a 30-foot wide sign panel. The "Cactus-Arrow" sign on a white background was the sign currently in use on the Illinois Tollway system, installed 1 and ½ mile in advance of the toll plaza. Two virtually identical test signs were presented in the simulation at distances of 1 and ½ mile in advance of the toll plaza for each test run, with the only difference being the distance to the toll plaza at the top of the sign panel.

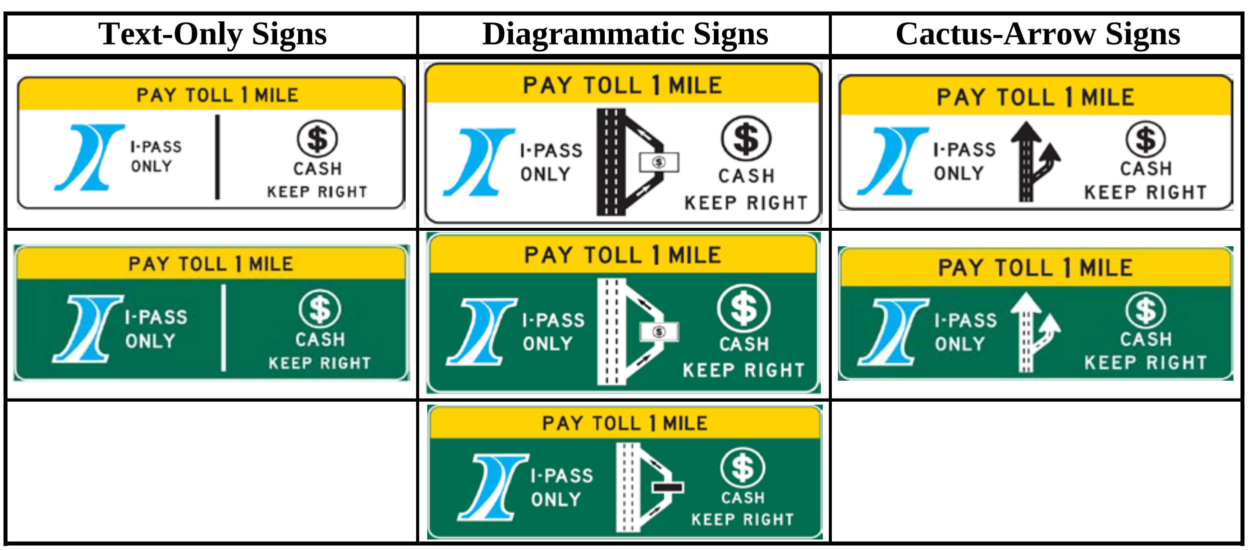


Figure 1 Laboratory Simulation Study Experimental Signs.

Figure 2 illustrates representative candidate signs under each of the lighting conditions tested in the laboratory study.

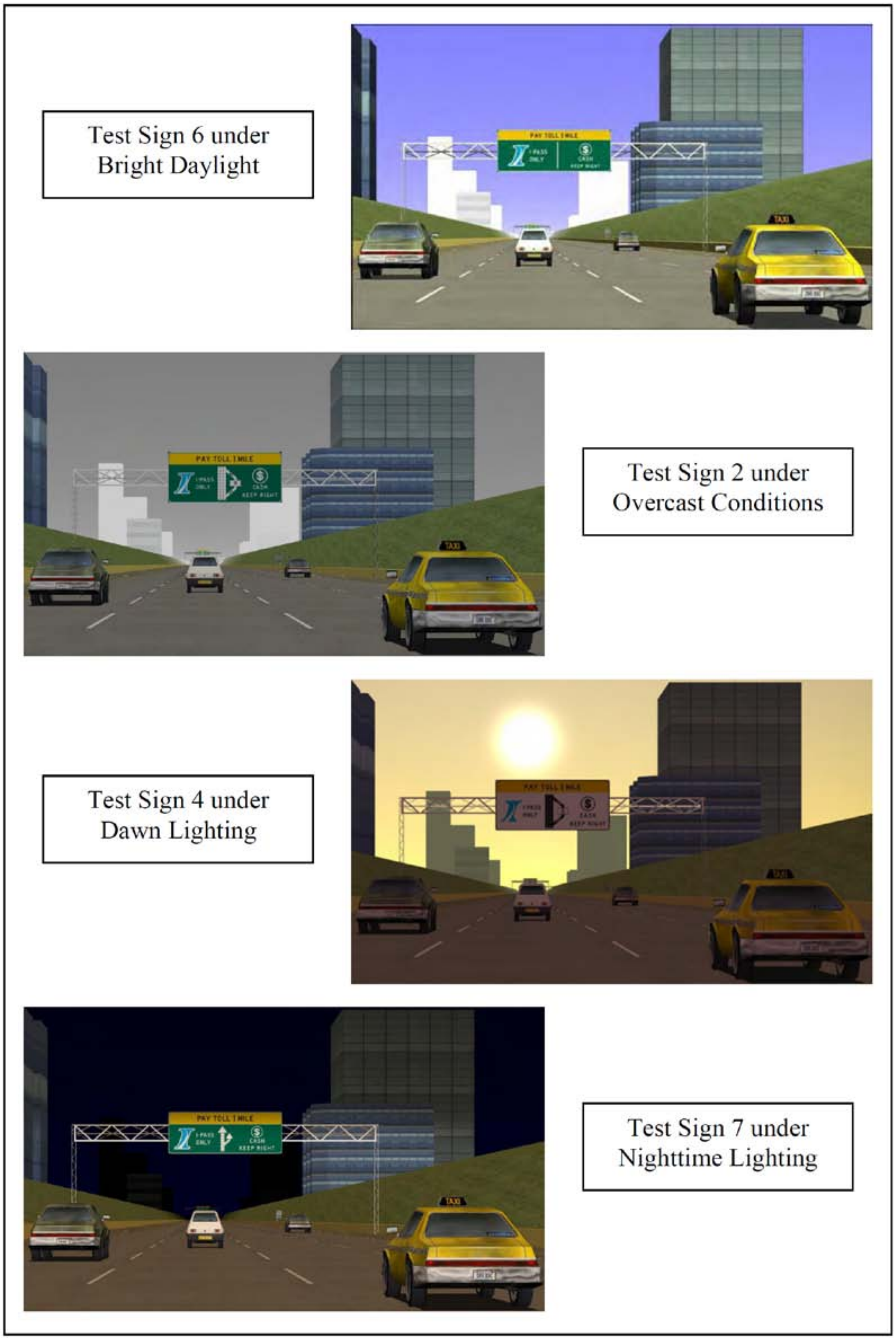


Figure 2 Representative Candidate Signs Under Each Lighting Condition

To complement the simulation testing, pre-test and post-test surveys were administered to subjects. The pre-test survey generally focused on basic driver information, such as how often the participant used the Illinois Tollway, their age, how long they had been licensed to drive, their visual health, whether they used corrective glasses or contact lenses, and whether they possessed/used an I-PASS transponder. The post-test survey focused on the signs that they viewed in the simulation, and attempted to determine which signs they preferred and why. In this way, the study was able to collect both stated sign preferences (via the post-survey) and sign performance (via the empirical driver-reaction data collected during the simulation runs).

Following the driving simulator, subjects completed a questionnaire concerning their opinions on the signs they saw in the experiment. For example, subjects were asked to rate each sign on a scale of 1 to 7, based on three criteria: Overall Opinion, Ease of Comprehension and Legibility from a Distance. They were also asked to write positive and negative comments on each sign, and sketch their ideal sign.

Figure 3 illustrates the test setup in use.

Figure 3 Simulation Under Dawn Lighting Conditions.

Each subject completed 12 test runs. At the beginning of the simulation, the test facilitator explained the objectives of the test and subjects conducted one or two dry runs with the signs on the overhead trusses blanked out to familiarize them with the test setup. The test runs presented one of the seven signs under one of four lighting conditions, selected at random. At the end of each test run, the facilitator initiated the next, randomly selected, scenario. Subjects were not informed that the sign recognition distance and comprehension time were being recorded by the simulation program.

For each test run, subjects were instructed to pay either with cash or I-PASS after they passed the first test sign. In addition, if a subject's test runs included both 10 and 12-foot versions of a sign, the 10-foot sign was presented first in their sequence of test runs. This was done to ensure that recognition distance and comprehension time data for the smaller sign was obtained first to avoid confounding the results.

Laboratory Study Results

Empirical data was recorded electronically by the simulation program. Pre- and post-test survey results were quantified and analyzed. The results of the laboratory study were mixed.

Based on the simulation test, the 12-foot high Diagrammatic Signs on average performed best: the white-background Diagrammatic Sign had the best (longest) recognition distance and the green-background Diagrammatic Sign had the best (shortest) comprehension time. Interestingly, the green-background Diagrammatic Sign performed poorly in the recognition measure. Additionally, the 10-foot tall Diagrammatic Sign performed significantly worse than the 12-foot tall version.

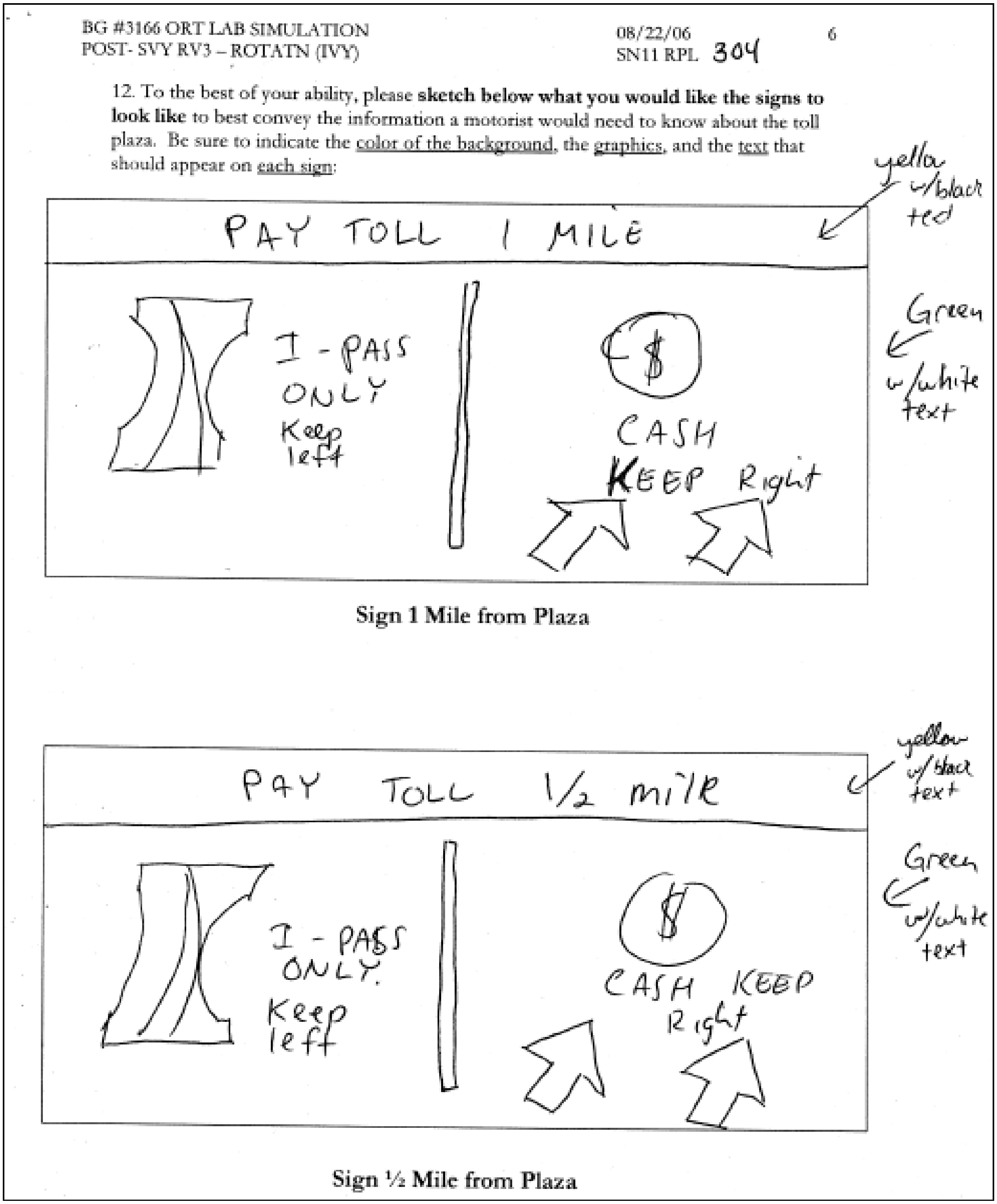
On the Sign Opinion Questionnaire portion of the test, the white-background Text-Only Sign was most preferred overall. However, test subjects who use the I-PASS electronic toll payment transponders preferred the white-background Cactus Arrow Sign, which is the current standard sign used on the Illinois Tollway System at ORT Plazas. Also, the green-background Diagrammatic Sign performed very poorly.

Lane position/change data was reviewed and determined to be not as relevant. Some drivers preferred making multiple lane changes while others tended to stay in their lane.

The post-test survey also asked subjects to sketch the "ideal" sign that would most effectively convey relevant toll plaza and payment information to drivers. Subjects were asked to identify sign characteristics such as background colors, graphics, banners and messages (text) on their ideal sign.

Figure 4 presents a sample sign design sketched by a test subject.

The final conclusion was that most of the signs warranted inclusion in the field study. For the field test, the current (Cactus Arrow on white background) signs would be used in one direction at each plaza as a control site. Based on the simulation study, the 10-foot tall, green-background, diagrammatic sign was eliminated for the field study. It was noted that while subjects reported a preference for white-background, text-only signs in the post-test survey, they actually performed better with the diagrammatic signs during the simulation.



BG #3166 ORT LAB SIMULATION
POST- SVY RV3 – ROTATN (IVY)

08/22/06
SN11 RPL 304

6

12. To the best of your ability, please **sketch below what you would like the signs to look like** to best convey the information a motorist would need to know about the toll plaza. Be sure to indicate the color of the background, the graphics, and the text that should appear on each sign:

Sign 1 Mile from Plaza

Sign ½ Mile from Plaza

Figure 4 Sample Test Subject Sign Design

FIELD STUDY

Field tests were conducted in the second phase of the Illinois Tollway's ORT Plaza Advance Signing Experiment. For the field test, the standard ORT Plaza approach signs were replaced with one of four experimental signs at four mainline toll plazas on the Illinois Tollway (Plaza 9 – Elgin, Plaza 24 - Edens Spur, Plaza 35 – Cermak, and Plaza 73 – Army Trail Road) for a 10 month period between March and December, 2007. The test signs were as follows: the 12-foot tall Diagrammatic sign and the Text-Only sign, each on a white and green background. The white-background, Cactus Arrow signs were already in use in the control direction. One set of each sign (one at the 1-mile location and another for the ½-mile location) was fabricated. The test signs were rotated among four test plazas, and installed at each plaza for at least two months.

The four test plazas were chosen based on a several factors. First, they provide a variety of ORT lanes (Plaza 24 has two lanes, Plazas 9 and 73 have three lanes, and Plaza 35 has four lanes). Additionally, most of the plazas have a high degree of recreational and occasional travelers. Plazas 9 and 24 have unique summer weekend characteristics with travel to and from Wisconsin. Plaza 35 is the largest plaza on the Illinois Tollway system and handles a large volume of commercial vehicle traffic bypassing the urban expressways in Chicago. Plaza 73 serves a larger proportion of commuters, but with increased regional recreational traffic off peak. Finally, the ORT construction at these four plazas was complete prior to project initiation. Figure 5 illustrates the location of the test plazas selected for the field test.

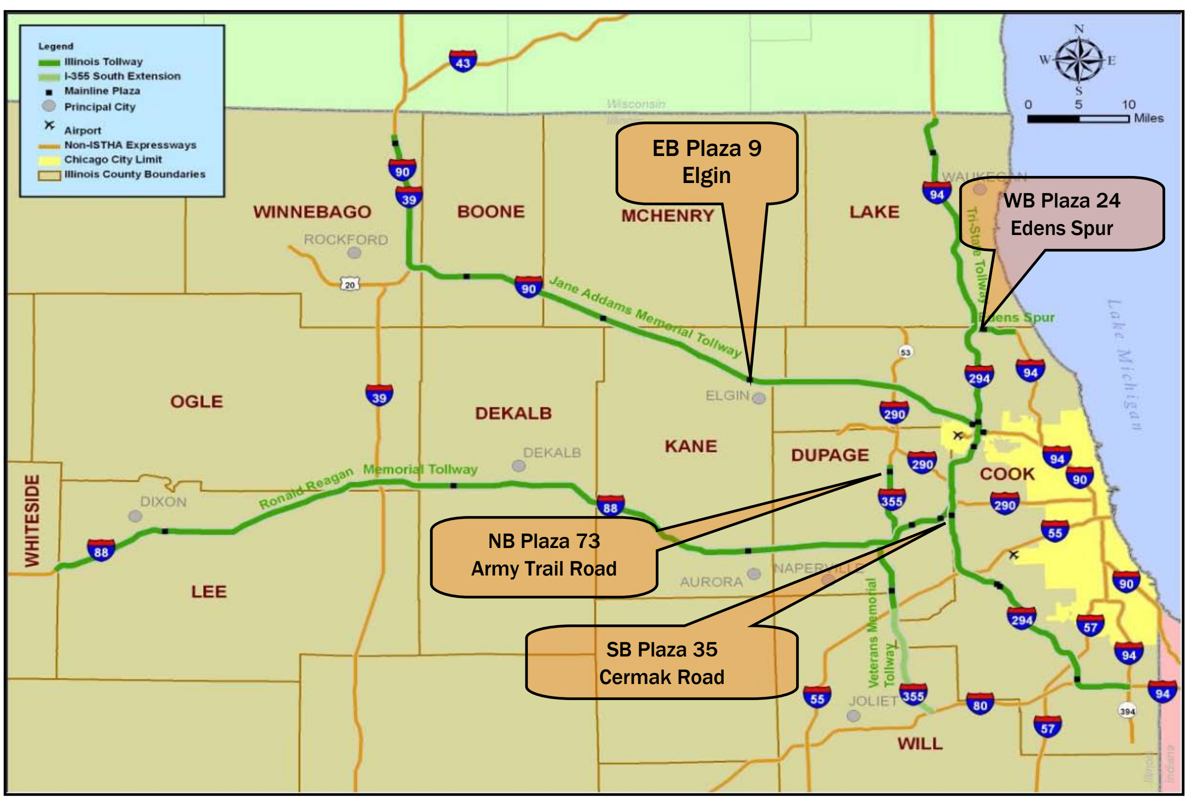


Figure 5 Field Test Locations.

Figure 6 illustrates the sign rotation schedule used in the field test.

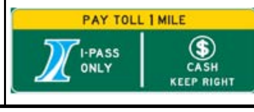
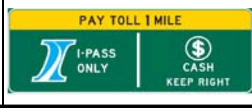
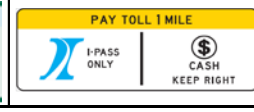
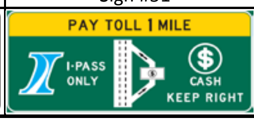
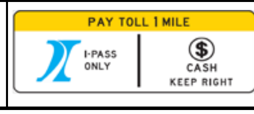
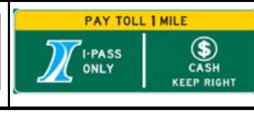
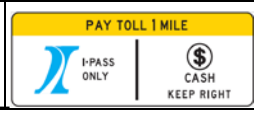
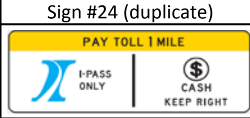
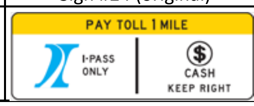
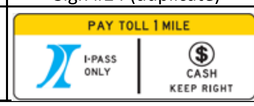
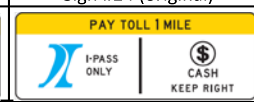
Test Sign Location		Test Period #1	Test Period #2	Test Period #3	Test Period #4
Eastbound Plaza 9 (I-90 at Elgin)	Installation Date	**March 5, 2007**	**June 7, 2007**	**August 8, 2007**	**October 16, 2007**
	Sign Number	Sign #24 (original)	Sign #32	Sign #43	Sign #51
	Sign Panel				
Westbound Plaza 24 (I-94 at Edens Spur)	Installation Date	**March 12, 2007**	**June 6, 2007**	**August 7, 2007**	**October 15, 2007**
	Sign Number	Sign #32	Sign #43	Sign #51	Sign #24 (duplicate)
	Sign Panel				
Southbound Plaza 35 (I-294 at Cermak)	Installation Date	**March 19, 2007**	**June 5, 2007**	**August 6, 2007**	**October 18, 2007**
	Sign Number	Sign #43	Sign #51	Sign #24 (original)	Sign #32
	Sign Panel				
Northbound Plaza 73 (I-355 at Army Trail Road)	Installation Date	**March 26, 2007**	**June 4, 2007**	**August 9, 2007**	**October 17, 2007**
	Sign Number	Sign #51	Sign #24 (duplicate)	Sign #32	Sign #43
	Sign Panel				
Sign Storage	Sign Number	Sign #24 (duplicate)	Sign #24 (original)	Sign #24 (duplicate)	Sign #24 (original)
	Sign Panel				

Figure 6 Sign Rotation Schedule.

Development of Measures of Effectiveness

Prior to starting the field test, an inventory of available data was conducted to determine possible measures of effectiveness (MOEs). The Illinois Tollway records hourly traffic volume data at all toll plazas based on toll transactions. This was helpful in determining rates, but traffic volume itself was not considered directly related to the effectiveness of the toll plaza signing.

Crash data was available for the entire Illinois Tollway system. The study team decided to examine all crashes occurring within two miles approaching each toll plaza. Consideration was also given to counting lane changes. Unfortunately, there was no practical and reliable way to count lane changes over the mile or so in advance of the toll plaza, and not all lane changes beyond one mile from the plaza are related to lane choice decisions at the toll plaza (although the proportion of lane changes should increase closer to the decision point.)

Consideration was given to examining brake lights approaching a toll plaza as an indication of driver confusion. Unfortunately, the Closed Circuit Television Cameras (CCTV) cameras on the Illinois Tollway were not well positioned to record rear views of cars approaching the decision point. The study team investigated installing additional cameras in the suitable locations, but power, communications, and safety could not all be addressed in a cost effective manner.

Examination of lane-specific speeds and traffic counts approaching the plazas were also considered. The Illinois Tollway has numerous roadside-mounted microwave (RTMS) sensors deployed at spot locations in the system that were capable of providing lane specific information. Unfortunately, many of the plazas provide additional lanes for weaving and diverging traffic close to the plaza. The lane distribution data becomes less meaningful due to the new traffic and additional lanes. Furthermore, two of the test plazas were located near termini of the Illinois Tollway system and did not have an RTMS sensor on one approach to the plaza.

Finally, the study team considered using gore crossings at the plaza as a measure of effectiveness. The vast majority of gore crossings at this late point are directly related to driver confusion. The team tested several automated means of collecting the data, finally settling on video data collection using existing CCTV cameras. A decision was made to collect several hours of video and have staff manually count the number of crossings. Illinois Tollway CCTV cameras were well positioned to gather this data.

The MOEs selected included crash rates approaching the plaza and gore crossings at the plaza. The RTMS speed and lane count data was given an initial examination and determined to not be relevant to this effort.

Field Data Collection

Crash data was collected monthly and applied to the appropriate test sign. This data was then analyzed to determine the number of crashes that occurred within two miles upstream of one of each test plaza. Traffic volume data from the toll plazas and seasonal variations were used to determine the crash rate for each sign. It was recognized from the beginning that this data may be of limited value, since crash analysis typically requires several years of data (typically a minimum of 3 years) while the study only provided 2 months experience with each sign. Despite our optimism, the crash data did not show any particular sign as being more effective at reducing crash rates. Furthermore, due to the relative infrequency of crashes, a single sign may have a very low rate at one plaza and a high rate at another. As such, the validity of this data was discounted.

Gore crossing data was also analyzed. Each ORT plaza has a nearly 1/4-mile long painted gore at the diverge between the ORT and Conventional/Cash plazas. While there are several reasons a vehicle may cross the gore area, one of the primary reasons is driver confusion. The analysis was very careful to avoid periods of heavy traffic congestion. A backup in the ORT lanes could lead to last minute lane changes between the ORT lanes and conventional plaza lanes, and vice versa. For each site, of the four hours of video collected, one hour was analyzed to collect gore crossing data. Again, traffic volumes from the toll plazas were used to normalize the gore crossing data by computing gore crossing rates. The results clearly showed that the Green Diagrammatic Sign performed best on this measure, summarized in Figure 7.

While examining this data, one additional issue became apparent. The gore crossings for southbound Plaza 35 (Cermak) were significantly higher than the other approaches. Additional investigation revealed that the greater issues for this plaza are the approach roadway geometry (being on a curve) and the interchange spacings (having nearby system interchanges). In such instances, roadway signing alone may not be adequate to reduce gore crossings and improve safety. Rather, the overall geometry and traffic operations of the plaza approach area must be considered as a whole.

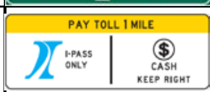
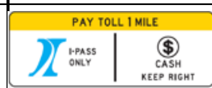
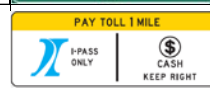
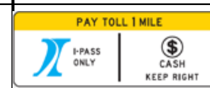
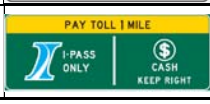
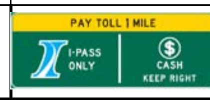
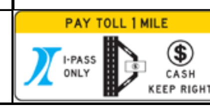
	Rate of Gore Crossings Per 10,000 Vehicles							
	Plaza 9		Plaza 24		Plaza 35		Plaza 73	
Ranking	Sign	Gore Crossing Rate	Sign	Gore Crossing Rate	Sign	Gore Crossing Rate	Sign	Gore Crossing Rate
Best		14		102		326		31
2nd		30		116		477		100
3rd		31		147		482		154*
Worst		32		229		539		219

Figure 7 Gore Crossing Results.

Motorist Survey Design

In addition to the field data collection, a large scale motorist survey was conducted. As previously mentioned, the focus groups and laboratory study utilized a small sample of test subjects. The initial web-based survey did involve more respondents, but they were all I-Pass users (those most familiar with the Illinois Tollway and its operations). The motorist survey provided an opportunity to collect information directly from motorists regarding the test signs. The intent of the motorist survey was to target those drivers unfamiliar with the Illinois Tollway and to collect information from a much larger sample to see if their opinions matched those from the earlier efforts.

The Illinois Tollway remains concerned about customer issues. Conducting a survey was the most direct method to obtain customer feedback regarding ORT plaza signing. The survey was viewed as a critical component since, as determined from the Laboratory study, sign preferences and empirical sign performance data often provide divergent results.

The survey consisted of 13 questions. Six questions collected demographic information and data on the motorists usage of the Illinois Tollway. The remaining seven questions asked respondents for their opinions on ORT toll plaza signs. Room was provided for written feedback. Survey cards were both mailed to I-PASS users and distributed to Illinois Tollway customers at the four test plazas on one weekday and one weekend day in August 2007. While I-PASS users represent the majority of the traffic, surveys were distributed to approximately 5% of the I-PASS customers and 20% of the cash customers at each of the four plazas.

Motorist Survey Results

In all, nearly 40,000 surveys cards were distributed at the plaza and more than 3,700 completed surveys were received. In addition to some demographic and driving pattern questions, the survey asked drivers to identify the sign they saw most frequently, and to rate that sign on four measures:

- Overall Impression of the Sign
- Helpfulness of the Sign
- Ease of Understanding the Sign
- Visibility of the Sign at a Distance

Respondents were then asked to indicate their preferred sign, irrespective of which sign they saw most frequently. Based on respondent ratings, the **Green Diagrammatic** sign scored highest on all four questions. In response to which sign was most preferred, drivers most frequently chose the **White Diagrammatic** sign.

The survey also asked respondents how they would improve their preferred sign. Approximately 1,850 respondents, nearly half of the total, provided written comments. Nearly one-quarter of respondents had no changes to recommend to their preferred sign. The next three responses offered specific direction

- 21% of respondents suggested that the cash toll rate for passenger cars should be shown on the signs;

- 8% of respondents commented that the 1-Mile and ½-Mile signs should contain down arrows specifying the destination of each lane, as is done on the third sign in the current ORT Signing Scheme; and,

- 8% suggested that the overhead signs be placed further upstream of the plaza, such as starting at 2 miles to allow drivers more time to make lane changes, and among these respondents some indicated a need for more than two advance ORT signs.

CONCLUSIONS

The overall intent of this study was to use signing to improve motorist safety at ORT toll plazas. Much was learned from this project that will be used to accomplish this goal. The results of this study were included in comments on proposed revisions to the MUTCD addressing toll plaza traffic control devices.

Both the Laboratory and Field studies used a combination of empirical and subjective analyses. Among the four empirical measures utilized between the two studies, the Diagrammatic Signs clearly performed best. Table 5 compares conclusions based on empirical data collected in the Laboratory and Field studies.

Table 5 Comparison of Empirical Data between Lab and Field Studies

Laboratory Study	Field Study
Recognition Distance: The **White Diagrammatic** sign had the longest/best recognition distance (based on average values). **Comprehension Time:** The **Green Diagrammatic** sign had shortest/best comprehension time.	**Gore Crossings:** **Green Diagrammatic** performed best on gore crossings. **Crash Rates:** Crash Rates did not appear to be impacted by signs. Rather, crash rates at ORT Plazas went down in both test and control directions over the course of the Field study, indicating that drivers became generally more familiar with the ORT Plaza configuration.

Respondents stated preferences were mixed between the two studies. Table 6 summarizes the survey results. In the Laboratory study, the white background text-only sign was preferred overall, while many participants expressly disliked the diagrammatic signs. In contrast, respondents to the Field Study survey clearly favored the Diagrammatic Signs. Given the far larger sample size of the Field Study survey, and the real-world test-sign experience of the Field Study survey respondents, more weight is given to the results of the latter survey.

Table 6 Comparison of Stated Preference/Survey Data between Lab and Field Studies

Lab Study Survey	Field Study Survey
White Text-Only sign was preferred overall on all questions that asked about the six test panels. On the sign rating questions **White Cactus Arrow** signs were preferred by I-PASS users.	**Green Diagrammatic** performed best on Field Study survey ratings (Questions 8-10). **White Diagrammatic** was most preferred among test signs (Question 11)

Overall, Diagrammatic signs were the clear winner among the empirical tests, and on the Field Study survey. Between the two background colors the Diagrammatic Sign with the green background ranked higher more consistently among the various measures. Therefore, based on the results of its signing experiment, the Illinois Tollway plans to move ahead with the 12-foot tall Green Diagrammatic Sign.

Summary

The primary object of the experiment was to determine which sign was most effective at informing drivers and improving ORT toll plaza safety and operations. However, the experiment also produced a number of other significant findings, which the Illinois Tollway planned to incorporate into the future design and enhancement of ORT Plazas.

1. Roadway geometry and ramps within two-miles upstream and downstream of ORT plazas affect driver behavior and safety. Plaza design and improvements must consider all of these aspects, not just approach signing; and,

2. Customers have indicated their preferences for further improving advance ORT toll plaza signs. These include: including the cash passenger car toll cost, adding lane assignment arrows to approach signs, and warning drivers further in advance of ORT plazas.

During the experiment, the Illinois Tollway (along with the rest of the transportation community) reviewed the Notice of Proposed Amendments (NPA) for the MUTCD. The findings of this study are in agreement with findings and overall recommendations of the MUTCD. In the short term, the Illinois Tollway planned to implement a modified Green Diagrammatic sign that also includes additional elements as proposed in the MUTCD. Figure 8 illustrates the typical signing that will be used at approaches on the Illinois Tollway. Other changes such as roadway geometric modifications will be addressed over the longer term.

The laboratory simulation approach presented here provided a cost-effective and quick way to test the effectiveness of alternative ORT sign designs. Development of the simulation was accomplished for twenty five thousand dollars, while participant recruitment and administration of the laboratory study cost thirty thousand dollars. In comparison, fabrication and installation of an individual 10 foot tall by 30 foot wide sign panel used in the field study cost approximately ten thousand dollars. The simulation study thus served as an effective way to screen candidate signs for inclusion in a subsequent, more comprehensive field test.

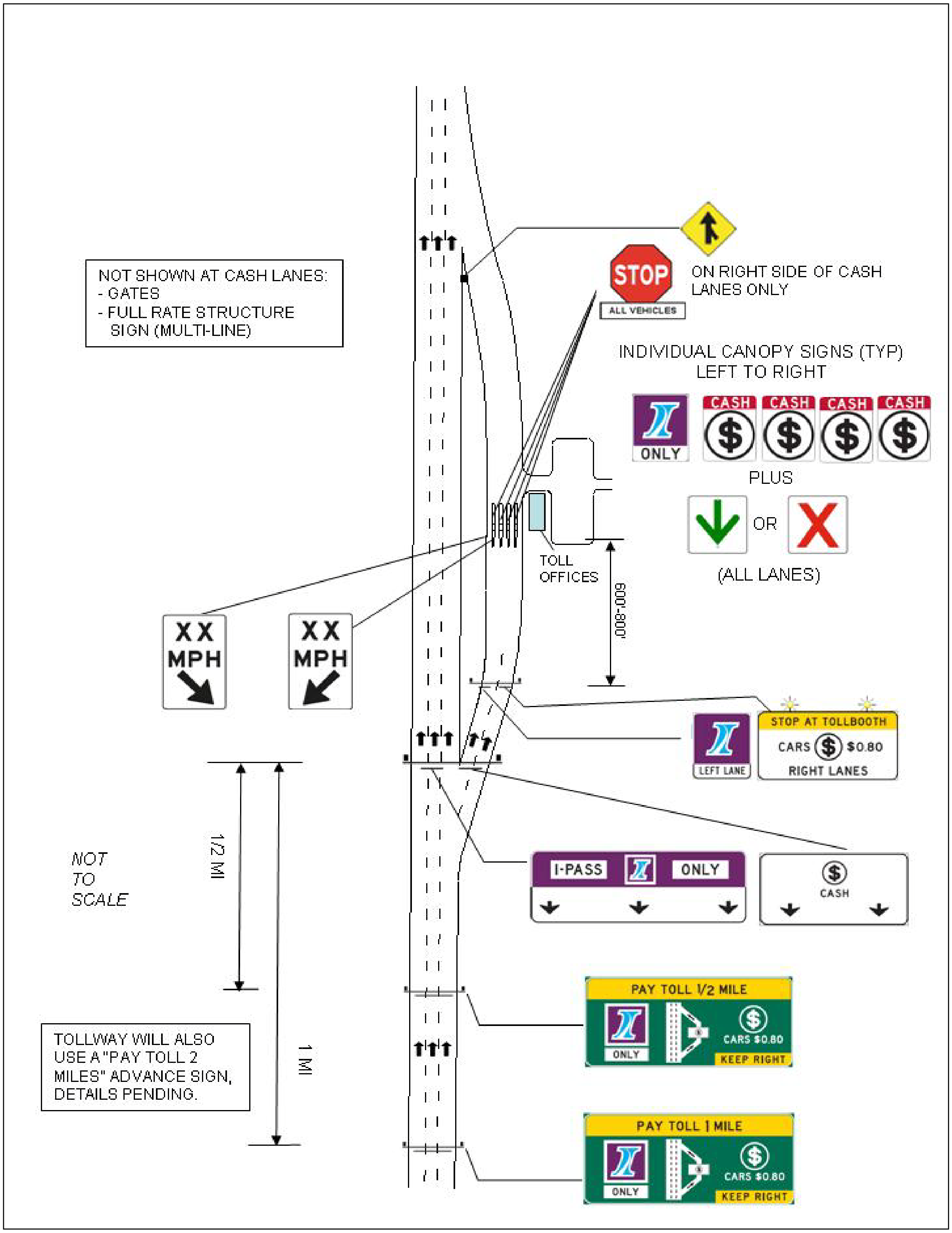


Figure 8 Typical Signing At Mainline Toll Plazas.

ACKNOWLEDGEMENTS

The results of this study were previously presented at a poster session of the 2009 Annual Meeting of the Transportation Research Board.

REFERENCES

Schaufler, A.E. (1997). "Toll Plaza Design". *National Cooperative Highway Research Program, Synthesis of Highway Practice* 240.

Stammer, R.E., Jr. and McDonald, D.R., Jr. (2000). "Tollway Sign and Pavement Markings – Recommended Design Guidelines". *Transportation Quarterly,* Vol. 54, No. 3, 2000, 67-83.

Federal Highway Administration, U.S. Department of Transportation (2003). *Manual on Uniform Traffic Control Devices for Streets and Highways.*

Federal Highway Administration, U.S. Department of Transportation (2006). *State of the Practice and Recommendations on Traffic Control Strategies at Toll Plazas*.

U.S. Department of Transportation. *Federal Register*, Part III, Vol. 73, No. 1, National Archives and Records Administration. January 2, 2008.

Golembiewski, G., Knoblauch, R. and Center For Applied Research, Inc. *Traffic Control Devices Pooled Fund Study: Traffic Control Devices at Transponder-Controlled Tollbooth Lanes*, Final Report, December 2004.

Pisano, P. "Developing a Standard Approach for Testing New Traffic Control Signs". *Public Roads*, June 1992.