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The Effectiveness and Safety of Traffic and Non-Traffic Related Messages Presented on Changeable Message Signs—Phase II

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16. Abstract (Limit: 200 words)

In Phase II of this investigation, we used a fully interactive PC-based STISIM driving simulator, to conduct two experiments which were similar to experiments in Phase I. The participants were 120 licensed drivers from three age groups—18-24, 32-47, and 55-65 years old—who drove, in free flow traffic, for approximately 20 miles on a four-lane freeway before encountering target messages on Changeable Message Signs (CMSs). The Phase II CMS messages were clearer and less complex than those used in Phase I. In the first experiment the target message was changed to "Road Closed/Crash Ahead/Use Thompson Exit:" 93.3% of the participants took the exit—as compared to 55.8% in Phase I. In the second experiment, the message was changed to "Abducted Child/Tune To/Radio 88.5 FM:" 71.7% of the participants (71.7%) could remember enough information to enable them tune to 88.5 FM—as compared to 8.3% who could recall some vehicle information and at least five license plate letters and numbers from the Phase I CMS ("AMBER Alert/Red Ford Truck/ MN Lic# SLM 509"). Some participants reduced speed on approaching the CMSs, suggesting similar reductions could occur in real world driving in free flow conditions. However, when traffic is congested speeds are typically slower, and drivers are less likely to reduce speed still further to read CMSs.

We conducted a survey which showed drivers think it is very useful to have information about traffic problems and roadway maintenance schedules on CMSs. Also, we analyzed real-world traffic speed data obtained when CMS messages were deployed. Finally, we conducted observations at Mn/DOT's Regional Transportation Management Center (RTMC), focusing on the decision-making processes involved when traffic-related CMS messages are deployed.

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The Effectiveness and Safety of Traffic and Non-Traffic Related Messages Presented on Changeable Message Signs—Phase II

Final Report

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Executive Summary

1. Introduction

This report describes Phase II of an investigation into the effectiveness and safety of traffic and non-traffic related messages presented on Changeable Message Signs (CMSs), conducted for the Minnesota Department of Transportation (Mn/DOT). In Phase II, we used a fully interactive PC-based STISIM driving simulator to conduct two experiments that were directly comparable with two experiments carried out in Phase I. In Phase II, the participants were 120 licensed drivers from three age groups (18-24, 32-47, and 55-65 years old). The participants drove, in low level traffic, for approximately 20 miles on a four-lane freeway before encountering a target CMS. In the first experiment, the target message advised participants to leave the freeway at a specific exit and, in the second, the target message was an "Abducted Child" message. We investigated the comprehensibility of both messages and determined whether or not participants reduced speed as they approached them. Also, we conducted a survey dealing with travel time information and other traffic-related information presented on CMSs. In addition, we analyzed real-world traffic speed data obtained when CMSs were deployed. Finally, we conducted observations at Mn/DOT's Regional Transportation Management Center (RTMC), focusing on the decision-making processes involved when traffic-related CMSs are deployed.

2. Effect of Clarifying the "Use Thompson Exit" Message

In the first Phase I experiment, the target CMS message read "Crash/ At Wyoming Ave/ Use Thompson Exit." In that experiment, 67 of 120 participants (55.8%) took the Thompson Exit. In the first Phase II experiment, the first and second lines of the target message were changed to "Road Closed/Crash Ahead"—but the third line was left unchanged. In this experiment, 112 of the 120 participants (93.3%) took the Thompson Exit. The increase in the number of participants who took the Thompson Exit in Phase II was highly statistically significant. The changes to the first two lines of the Phase II message made it clearer that there was a problem on the freeway ahead, and omitting details of the location (Wyoming Ave) of the problem, reduced the likelihood that participants would misunderstand which freeway exit they should use.

3. Effect of Reducing the Complexity of the "Abducted Child" Message

In the second Phase I experiment, the target message read "AMBER Alert/Red Ford Truck/ MN Lic# SLM 509." Only two of the 120 participants could correctly recall all of the information on the CMS and just 10 participants (8.3%) could recall some vehicle information and at least five of the six letters and numbers on the license plate. For the second Phase II experiment, the message was changed to "Abducted Child/Tune To/Radio 88.5 FM." In this experiment, 86 of the 120 participants (71.7%) could remember enough information to enable them tune to 88.5 FM. The improvement in the number of participants who obtained sufficient information to respond to the Phase II message was highly statistically significant. The change in the first line of the message clarifies the more obscure term "AMBER Alert." The changes to the second and third lines are more radical. Information that is hard to remember (vehicle details and license plate number) was replaced with easier to encode information (the radio call sign). These changes alter the way drivers would obtain information. They would be directed to a radio station, where they could hear the complete "Abducted Child" message. Repetition of the message would make it far more likely that drivers would retain the information, and would be more likely to recognize a vehicle involved in an "Abducted Child" incident. Mn/DOT already uses the term “Abducted Child” in CMSs. The results obtained with “Tune To/ Radio 88.5 FM” in the second and third lines of the message, strongly suggest that making this change in the “Abducted Child” CMS would be beneficial.

4. Reductions in Speed on the Approach to the Target Messages

In the Phase I and II experiments, we investigated reductions in speed on the approach to the target messages. We compared the speed of individual participants in two road segments. In the first segment, between 1,860 feet (566.9 meters) and 860 feet (262.1 meters) from the target messages, they were too far from the messages to be able to read them. In the second segment, between 860 feet (262.1 meters) and 0 feet (0 meters) from the messages, the participants were within the range where it was possible to read them. In the first Phase I experiment, on the approach to the “Use Thompson Exit” message, 16 of 120 participants (13.3%) reduced speed by 2 mph (3.2 km/h) or more as they drove from the first to the second segment. In the first Phase II experiment, 31 of 120 participants (25.8%) reduced speed by 2 mph (3.2 km/h) or more between these segments. However, for speed reductions of 5 mph (8.0 km/h) or more, the numbers were the same in Phase II and Phase I. Also, for extreme speed reductions of 9 mph (14.5 km/h) or more, there were no Phase II participants in this range while there were four participants in Phase I. In the second Phase I experiment, on the approach to the “AMBER Alert,” 26 of the 120 participants (21.7%) reduced speed by 2 mph (3.2 km/h) as they drove from the first to the second segment. In the second Phase II experiment, 28 of the 120 participants (23.3%) reduced speed by 2 mph (3.2 km/h) or more as they drove from the first to the second segment on the approach to the “Abducted Child” message. The numbers of participants who reduced speed were similar in all speed ranges, from 2 mph (3.2 km/h) to 14 mph (22.5 km/h), for the second Phase I and Phase II experiment.

5. Survey Results

The Phase II participants completed a survey, which included questions about the value of travel time information, and other traffic-related information that may be presented on CMSs. They used a seven-point scale to assess the usefulness of this information. We found that the participants rated (1) information about traffic problems as being very useful—the average rating was very high (6.39 out of 7); (2) information about roadway maintenance schedules as being very useful—the average rating was very high (6.42 out of 7); (3) travel time information as useful—the average rating was 5.38 (out of 7). However, ratings for safety messages were mixed and, on average, somewhat negative.

6. Traffic Speed and Real-World CMS Messages

To explore the question of whether CMS messages affect traffic speeds in real world driving, we examined real-world speed data obtained by the RTMC when CMSs were deployed. The data were obtained from double loop detectors in the middle and right lanes of Southbound I-35W near 73rd Street. These double loop detectors are located a few hundred feet (between 100 and 300 feet) downstream from the nearest CMS. If drivers reduce speed on the approach to this CMS, then they may still be driving slower a few hundred feet after they have passed beneath it. These double loop detectors could not be relied on to provide accurate *absolute* speed data—they have not been calibrated for five years. However, they should provide reliable *comparative* speed data. Because of these problems, it was not meaningful to use the data obtained with the double loop detectors to make direct comparisons with the data obtained in the simulator experiments. However, we could determine whether or not there were reductions in traffic speed consistent with speed reductions that might be associated with the deployment of CMSs. We analyzed data obtained at the time that six incidents occurred. We compared data obtained on the day each incident occurred with comparable data obtained at the same time of day one week later. For comparisons to be meaningful, several criteria had to be met: (1) traffic volumes should be similar in the pre-deployment period on the test and comparison days; (2) traffic volumes should be similar during the deployment period on the test and comparison days; (3) traffic speeds should be similar in the pre-deployment period on the test and comparison days; and (4) traffic speeds should be similar in the pre-deployment and deployment periods on the comparison day. For five incidents, at least one of these criteria was violated. For the sixth incident, two consecutive CMSs were deployed. Our analysis showed that during deployment of the first message ("Incident on Ramp/At 90th St/Use Caution") and the second message ("Exit Ramp Closed/At 90th St/Use Other Routes"), traffic speeds for the middle lane *were* statistically significantly slower on the test day than on the comparison day—a result consistent with the suggestion that deployment CMSs can lead to slower speeds in real-world driving.

7. Observations of RTMC Operations

At the RTMC, we observed work processes in the Operations Center during morning and afternoon peak traffic periods, and conducted interviews with RTMC personnel. We focused on traffic operations and the decision-making processes involved in deploying CMSs. In the Operations Center, imagery is obtained, in real time, from approximately 430 surveillance cameras covering approximately 400 miles of roadways in the Twin Cities metropolitan area. Incident information is provided by State Patrol officers, FIRST units, and members of the public. The traffic operations operators use the surveillance cameras to find the best available view of incidents. Depending on the specific details of an incident, the operator decides whether to deploy a message on CMSs upstream from the incident, to warn oncoming drivers of potential hazard. The operator may decide to deploy messages on CMSs on roads feeding into the roadway on which the incident occurred. The operator makes the decision whether to deploy CMSs based on: (1) the severity of the incident, (2) the location of the incident, (3) where the incident occurs relative to the roadway (i.e., whether it affects one or more lanes, or is on a shoulder), (4) current traffic conditions, (5) how the incident is likely to affect traffic flow, and (6) his or her knowledge and experience. The operator monitors incidents as they evolve, modifying the text of the CMSs as necessary. If there are reductions in speed upstream from an incident, the operator may deploy additional CMSs still further upstream, or on feeder roads. During our visits to the Operations Center, the operators responded to the incidents rapidly and managed them very efficiently. In peak periods, when there is poor weather, there are more incidents and, consequently, it is considerably more difficult to manage them. However, we believe that the decision-making processes that the RTMC Operations Center personnel currently have in place are sound and very efficient**.**

Chapter 1
Introduction

1.1 Changeable Message Signs

This report presents the results of the second phase of an investigation into the effectiveness and safety of traffic and non-traffic related messages that are presented on Changeable Message Signs (CMSs). CMSs are traffic control devices designed to display messages that can be varied. They are also known as Variable Message Signs (VMSs), Dynamic Message Signs (DMSs), and Electronic Message Signs (EMSs). For the sake of consistency and simplicity, throughout this report they are referred to as Changeable Messages Signs (CMSs)—this is the way in which the Federal Highway Administration's "Manual on Uniform Traffic Control Devices (MUTCD, 2004) refers to them.

The guidelines for CMSs presented in MUTCD (2004, Section 2A-07), state that, "Except for safety or transportation-related messages, changeable message signs should not be used to display information other than regulatory, warning, and guidance information related to traffic control." However, CMSs are used for other purposes: For example, many states—including Minnesota—use CMSs to display AMBER Alerts as part of the AMBER (America's Missing—Broadcast Emergency Response) Plan. The Minnesota Department of Transportation (Mn/DOT) displays AMBER Alerts on CMSs, whenever they receive a request to do so from the Minnesota Department of Public Safety. When Phase I of this investigation was conducted in 2003, Mn/DOT used the term "AMBER Alert" on CMS displays. However, when we conducted Phase II in 2007, Mn/DOT was no longer using the term "AMBER Alert" in CMS messages, and was utilizing the term "Abducted Child" instead.

The various messages that State Departments of Transportation already present on CMS displays, or are considering presenting on them, can be assigned to the following three categories.

Category I: Time-critical, site-specific, CMS messages.
This category includes:

- Traffic-related messages that contain information about current conditions occurring at specific locations on the roadways, and that suggest ways in which motorists might deal with those conditions.
- Traffic quality messages such as those that present information on expected travel times to specific locations, or on traffic conditions that drivers are likely to encounter ahead. The content of traffic quality messages typically differs from one CMS display to the next, because these messages present information that is specific to the location of each CMS display. Also, if traffic quality messages are to be of value to drivers, they need be updated in real time in order to reflect changing traffic conditions.

Category II: Time-critical, non-site specific, CMS messages.
This category includes:

- AMBER Alerts (or "Abducted Child" messages), which are issued in cases of child abduction, when a child is in danger of serious bodily harm or death, and when descriptive information about the child, the suspect or the getaway car is available. These alerts are time critical because they are most effective in the first few hours of child abductions.

Category III: Non-time critical, non-site specific, CMS messages.
This category includes:

- Safety messages, such as "Don't Drink and Drive" or "Stay with Your Vehicle When Stalled."
- Transportation-related message, such as "Extra Troopers Working this Weekend." [Please note that although this message refers to a particular time period, it is not a time-critical message—like an AMBER Alert.]
- Law enforcement messages, such as "$100 Fine for Wrongful Use of HOV Lanes."

The fact that non-traffic related as well as traffic-related messages are presented on CMS displays raises the following issues about CMS messages, their usefulness, and their possible safety impacts on traffic:

- Whether or not drivers pay attention to CMS messages.
- Whether or not drivers respond to CMS messages.
- Whether there are differences in the responses of drivers to particular time-critical messages when *only* those time-critical messages are presented on CMS displays (and other CMS displays are left blank), and the responses of drivers to the same time-critical messages when non-time critical, non-site specific, messages are *always* presented on other CMS displays that motorists encounter.
- Whether or not particular messages presented on CMS displays cause drivers to slow down.
- Whether or not particular CMS messages impact traffic flow.

We began to address these issues in Phase I of our investigation into the effectiveness and safety of traffic and non-traffic related messages presented on CMS displays. Our research in Phase I and other recent research are briefly summarized below.

1.2 Previous Research

1.2.1 Phase I Study

In Phase I of our investigation into the effectiveness and safety of CMSs (Harder, Bloomfield, & Chihak; 2003), we conducted two experiments using a fully interactive, PC-based, STISIM driving simulator. The experiments were run back-to-back. In the first experiment, we investigated a time-critical, site-specific, CMS message and, in the second, we investigated a time-critical, non-site specific, CMS message. We determined the comprehensibility of both messages and whether or not drivers reduced speed as they approached them.

In both experiments, 120 participants drove approximately 20 miles (32.2 km) on a four-lane freeway, encountering five CMS displays in both drives. In both drives, the target messages (i.e., the time-critical, site-specific, CMS in the first experiment, and the time-critical, non-site specific CMS in the second) were presented on the fifth and final CMS display.

There were two display conditions in each experiment. Using a counterbalanced design, 60 participants were assigned to each condition. For the participants assigned to Condition A, a non-time critical, non-site specific, message ("Stay With/Your Vehicle/When Stalled") was displayed on the first four CMS displays they drove beneath before encountering the target message on the fifth CMS display. In contrast, the participants assigned to Condition B drove beneath four blank CMS displays, in both experiments, before they encountered the fifth CMS display on which the target message was presented. In both conditions in both experiments, the participants encountered two guide signs indicating the distances to upcoming exits on the simulated freeway.

In the first Phase I experiment, the target message was the following time-critical, site-specific, CMS message: "Crash/At Wyoming Ave/Use Thompson Exit." At the end of the drive in the first experiment, 67 of the 120 participants (i.e., 55.8%) took the Thompson Exit. After completing both experiments, each participant was asked a series of questions. From the responses to these questions, we learned that 19 of the 53 participants who failed to take the Thompson Exit did not understand the message—some thought the message meant that there was a crash on the Wyoming exit, and others thought there was a crash on the freeway, but that a lane was still open. A further 19 of the 53 participants saw the message, but did not think it applied to them, and 12 of the 53 participants did not notice the message (three participants did not respond to this question).

In the second Phase I experiment, the target message was the following time-critical, non-site specific, CMS message: "AMBER Alert/Red Ford Truck/Mn Lic# SLM 509." After passing beneath the overpass on which this CMS message was presented, the participants were asked to pull over and questioned as to what the message was. We found that only ten of the 120 participants had "Excellent" recall scores (meaning that they were able to remember the "AMBER Alert" term, some of the vehicle information on the second line of the message, and at least five of the of the six letters and numbers on the license plate on the third line of the message). A further 62 participants had "Good" recall scores (they were able to remember the "AMBER Alert" term, some vehicle information, and part of the license plate number), while the remaining 48 participants had fair or poor recall scores. Gender significantly affected the recall scores—there were nine females and just one male in the "Excellent" recall category. Also after completing both experiments, the participants were asked what "AMBER Alert" meant. Responses were obtained from 114 of the 120 participants. Thirty-two of the respondents (i.e., 28%) did not know what the term meant.

There was no statistically significant difference between the response to either target message (the "Use Thompson Exit" message or the "AMBER Alert") of the participants in Condition A (who encountered the non-time critical, non-site specific, "Stay With/Your Vehicle/When Stalled" message on the first four CMS displays) and the response of the participants in Condition B (who encountered four blank CMS displays)

In addition to determining the effectiveness of the target messages, we also investigated whether or not the Phase I participants changed speed as they approached the target messages. We compared the speed of the participants in two road segments. In the first segment, the participants were between 1,860 feet (566.9 meters) and 860 feet (262.1 meters) from the location of the CMS display presenting the target message—throughout this 1,000-foot (304.8-meter) segment, the participants were too far away from the target messages to be able to read them. In the second segment, they were between 860 feet (262.1 meters) and 0 feet (0 meters) from the target messages—i.e., they were within the range where it was possible to read the messages. In the first experiment, 16 of the 120 participants reduced speed by at least 2 mph (3 km/h) in the second segment, when it was possible to read the "Use Thompson Exit" message. And, in the second experiment, 26 of the 120 participants reduced speed by at least 2 mph (3.2 km/h) in the second segment, in which it was possible to read the "AMBER Alert." In both experiments, these reductions in speed occurred when the participants were driving in free flow traffic.

1.2.2 Other Recent CMS Studies

Since we reported the results of the Phase I experiments, there have been several studies in which the effectiveness of CMS messages has been investigated. Three studies, all of which used real-world data, are of particular interest.

In the first of these studies, Chatterjee and McDonald (2004) utilized the results of a series of field trials, carried out in nine European cities in research projects performed between 1994 and 1999, to explore the effectiveness of CMS messages in providing information of various kinds—including incident information and travel time information. With incident messages, Chatterjee and McDonald found that the severity of the incident, the specific location of the incident, and the availability of viable alternative routes influenced the diversionary behavior of drivers. They also found that travel time information was effective in inducing route changes. In addition, Chatterjee and McDonald report that, when CMS messages were used to inform drivers of traffic conditions, network travel times improved and that, although the improvements were relatively small, driver perceptions of the benefits that the CMS messages provided were much higher.

In the second study, Huo and Levinson (2006) investigated the effectiveness of CMS messages in the Twin Cities metropolitan area. They used single loop detector data and a weighted Probit model to estimate the diversionary behavior of drivers. They considered a number of CMS messages displayed at a single CMS site on I-35E during September 2000; 35 of these CMS messages encouraged drivers to take an exit ramp. Huo and Levinson found that the content of messages had a significant effect on the diversionary behavior of drivers—there was more diversionary behavior with messages reporting incidents ahead than there was with messages reporting congestion ahead. Huo and Levinson also found that more drivers took the exit in the 10-minute periods *after* CMS messages recommending the exit were deployed than took the exit in the 10-minute periods *before* the messages were deployed.

In the third study, Foo and Abdulhai (2006) also investigated the impact of CMS messages on traffic diversion using single loop detectors. They considered 17 CMS sites located upstream of Express-Collector transfer locations on Highway 401 in Toronto, Canada. At these 17 sites, the CMS messages provided information about traffic conditions beyond the transfer locations.

Drivers could use this information to decide whether or not to take the next transfer route. Traffic patterns were determined using single loop detectors installed at the transfer locations. Foo and Abdulhai examined three years of loop detector data (from 2003 to 2005). They found that the information presented in the CMS messages could alter diversion rates by 5%, and divert as many as 300 vehicles per hour. The number of diverted drivers depended on the content and location of the CMS messages. The effect the CMS messages tended to be greater in the afternoon than it was in the morning. Also, Foo and Abdulhai found that the impact of the messages decreased over the test period—the diversion rates dropped from 6.5% in 2003 to 4.75% in 2005.

In addition to these studies investigating the effectiveness of CMS messages using real-world data, attempts have been made to determine the conditions under which CMS messages affect traffic flow. It is clear that some CMS messages affect traffic flow. For example, The San Francisco Chronicle (Lee, 2002) reported the following extreme case: At 7:23 a.m. on Friday August 30th, 2002, a California Highway Patrol officer asked his superiors to turn off an "AMBER Alert" on a CMS display near the Cordelia truck scales on Westbound I-80 in Solano County. The officer made the request because too many drivers were slowing down to read the two-phase CMS message.

Recently, Huey and Margulici (2006) attempted to determine whether or not traffic slowed when messages providing travel time information were presented on CMS displays on I-80 in Emeryville and Berkeley, California. Eastbound traffic encountered a CMS display presenting travel times to Carquinez Bridge, Fairfield, and Novarro; while the CMS display encountered by westbound traffic presented travel times to Downtown San Francisco, the San Francisco Airport, and the Oakland Airport. Huey and Margulici compared hourly loop data, obtained during periods when the CMS messages displayed travel time information in May and June of 2005, with control data obtained from the same loop detectors during the same time periods in May and June of 2004—before the CMS messages were implemented. Huey and Margulici's results were inconclusive: There was some suggestion that the travel time CMS messages might have slowed the eastbound traffic, but not when the traffic was already congested. However, there was no evidence of slow downs for the westbound traffic.

We believe that there are several possible reasons why Huey and Margulici might have failed to obtain clear evidence of speed reductions. First, there may have been changes in the traffic speeds between 2004 and 2005 that masked any effects that the CMS time travel information messages might have had. Second, the unit of measure used in the study—hourly traffic data—may not have been refined sufficiently to reveal any possible speed reduction effects. Third, there may be too much inherent variability in the data for speed reduction effects to emerge. Or fourth, the CMS time travel information messages actually may have had no effect on traffic speeds. It is worth mentioning in support of the later possibility that, while travel time CMS messages may be fairly complex, if drivers see them regularly at particular locations then the drivers are likely to become familiar with the messages. Because of this familiarity, the drivers may encode the invariant parts of the message (i.e., the three specific destinations) so that they are processed very rapidly. Then, the drivers will be able to process the remaining variable parts of the message (i.e., the particular travel times) very quickly and, as a result, may have no need to reduce speed in order to acquire the travel time information that they need.

1.3 Phase II Study

In Phase II of our investigation into the effectiveness and safety of traffic and non-traffic related messages presented on CMS displays, we conducted two experiments that were similar to the Phase I experiments. In addition, we added three extra elements to the Phase II investigation: (1) a survey dealing with travel time information and other traffic-related information that may be presented on CMS displays; (2) an analysis of real-world data when CMS messages are deployed; and (3) observation and analysis of operations at Mn/DOT's Regional Transportation Management Center (RTMC) when CMS messages are deployed.

1.3.1 The Phase II Experiments

In Phase II, we conducted two experiments that were formally similar to the two Phase I experiments. This allowed us to directly compare the results of the Phase I and Phase II experiments. At the conclusion of our Phase I report, we recommended that changes should be made in the wording of CMS messages in order to make them clearer and unambiguous. The Phase II experiments were conducted in order to determine what difference the use of clear and unambiguous messages would have on the responses of drivers.

1.3.1.1 Selecting the time-critical, site-specific, CMS message. As mentioned above, in the first Phase I experiment, 19 of the 53 participants who failed to take the Thompson Exit reported that they did not understand the message—which was "Crash/At Wyoming/Use Thompson Exit." Some of these participants thought that message meant there was a crash on the Wyoming exit, and others thought there was a crash on the freeway, but that a lane was still open. In Phase II, our aim was to present a clearer, less ambiguous message. The following alternatives messages were considered:

1. "Road Closed/Before Wyoming Ave/Use Thompson Exit."
2. "Crash/Ahead/Use Thompson Exit"
3. "Road Closed/Ahead/Use Thompson Exit"
4. "Road Closed/Crash Ahead/Use Thompson Exit"

These alternatives were considered in collaboration with Mn/DOT. The first alternative was rejected because its second line, "Before Wyoming Ave," gives more information than is strictly needed and could potentially cause confusion, perhaps leading some drivers to think they should exit at Wyoming Ave, instead of at Thompson Ave. The second alternative was rejected because its first line, "Crash," does not convey the message that the driver should not continue on the road as clearly as the term "Road Closed," which is the first line of the third and fourth alternatives. The third alternative was rejected because its second line, "Ahead," does not explain why the information that that road is closed was not available earlier—as it would have been if, for example, the road were closed because previously planned maintenance work was being conducted. In contrast, the second line in the fourth alternative, "Crash Ahead" makes it clear that the road is closed in response to an unplanned problem. After discussions with Mn/DOT, the fourth alternative was selected for the Phase II experiment.

1.3.1.2 Selecting the time-critical, non-site specific, CMS message. There were two problems with the "AMBER Alert" CMS that was used in the second Phase I experiment. First, the message was difficult to remember—as previously mentioned, only ten of the 120 participants had “Excellent” recall scores (i.e., could remember the “AMBER Alert” term, some of the vehicle information, and at least five of the of the six letters and numbers on the license plate). Second, 32 of the 114 participants who responded when asked what “AMBER Alert” meant did not know what the term meant. Again in Phase II, our aim was to present a message that was clear and unambiguous. We considered the following alternatives:

1. “Child Abduction/Tune To/Radio 88.5 FM”
2. “Abducted Child/Radio 88.5 FM”
3. “Abducted Child/Tune To/Radio 88.5 FM”

Both “Child Abduction” and “Abducted Child” are far less ambiguous than the term “AMBER Alert” that was used in Phase I. We discussed these alternatives with Mn/DOT. The first alternative was rejected because the phrase in its first line, “Child Abduction,” is a less direct way to express that a child has been abducted than the phrase “Abducted Child,” which is used in the first and second line of the second alternative and in the first line of the third alternative. The second alternative was rejected because it is preferable to direct drivers to “Tune To” the radio station rather than to omit this phrase—including the direction “Tune To” removes potential ambiguity in drivers’ minds regarding the role of 88.5 FM . At the conclusion of our discussions with Mn/DOT, the third alternative was selected for the Phase II experiment.

1.3.1.3 The experiments. In Phase II, we conducted two experiments using the STISIM driving simulator. One hundred twenty participants completed the experiemnts, which involved essentially the same driving scenario that was used in Phase I. The main difference in the Phase II experiments was that we changed the wording of both the time-specific site-specific message and the time-specific non-site specfic messages that appeared on the fifth CMS display at the end of the drive. In the first experiment, the time-specific site-specific message was changed to: “Road Closed/Crash Ahead/Use Thompson Exit.” And in the second experiment, the time-specific non-site specfic messages was changed to: “Abducted Child/Tune To/Radio 88.5 FM.”

We determined the effectiveness of the new time-specific traffic-related CMS message presented at the end of the first experiment, by comparing the number of participants who responded appropriately by taking the Thompson Exit, with the number of Phase I participants who took the Thompson Exit. And, we determined the effectiveness of the new time-specific non-site specific message presented at the end of the second experiment by comparing the ability of the participants to remember the crucial information in the “Abducted Child” message presented in Phase II with the ability of the Phase I participants to remember the crucial information in the “AMBER Alert.” We also examined the effect of the new messages on driving speeds—comparing the numbers of participants who reduced speed by 2 mph (3.2 km/h) or more in both experiments in Phase II with the numbers of drivers who similarly reduced speed in the Phase I experiments.

1.3.2 Additional Phase II Elements

In addition, to conducting the two Phase II simulation experiments, we also added three extra elements in Phase II. The first of these elements was a survey that dealt with travel time information and other traffic-related information that may be presented on CMS displays. This survey was administered to the 120 participants who completed the two simulation experiments. The second element involved examining real-world data obtained when CMS messages are displayed. The data were obtained from double-loop detectors positioned near a CMS site on I-35W in the Twin Cities metropolitan area. We examined the data in order to determine whether or not they were consistent with the possibility that the deployment of CMS messages is associated with traffic slow downs. The third element involved observing operations at Mn/DOT's RTMC, analyzing the way in which incidents are managed and CMS messages are utilized.

1.4 Organization of this Report

The remainder of this report describes the Phase II investigation into the effectiveness and safety of traffic and non-traffic related messages presented on CMS displays. The chapters are organized as follows:

- Chapter 2 describes the methods used to conduct the two simulation experiments.
- Chapter 3 presents the results of the simulation experiments.
- Chapter 4 presents the results of the survey.
- Chapter 5 details the analysis of real-world data obtained when CMS messages were deployed.
- Chapter 6 describes the results of our observations at Mn/DOT's RTMC.
- Chapter 7 summarizes our findings and presents our conclusions and recommendations.

Chapter 2
Method

2.1 Participants

As in Phase I, we recruited 120 participants. They were licensed drivers from one of the following three age groups: 18-24, 32-47, and 55-65. There were 40 participants in each age group. Within each age group, there were 20 males and 20 females. The participants were recruited from the Twin Cities metropolitan area, and all of them reported that they regularly commute on interstate highways in the metropolitan area. After completing the experiment, each participant was paid $50 for his or her participation.

2.2 Driving Simulator

Each participant drove in a fully interactive, PC-based, STISIM driving simulator. The simulator is comprised of an automotive-style seat for the driver, which faces a bank of three 17” CRT displays. Three PCs generate the virtual environment presented on the CRT displays. Figure 2.1 shows the arrangement of the three PCs used in the STISIM simulator.

Figure 2.1. The STISIM simulator used in this study.

The virtual environment displayed in both experiments in this study was a four-lane freeway. As well as showing the freeway ahead, in the upper right corner of the center display a small window provided a rear-view of the route that each participant was diving. Also, in the lower part of this display, the front of the simulated vehicle was shown, along with two dials—one to the left showing driving speed, the other to the right showing the RPM rate. Figure 2.2 shows a typical view of the simulated environment that participants saw on the center display in this study.

Figure 2.2. Typical view of the virtual environment seen on the center display of the simulator.

In addition to the rear view of the route provided by window in the upper right corner of the center display (shown above in Figure 2.2), there were two small windows in the side displays that simulated side-view mirrors.

Two small speakers that were located behind the three CRT displays generated the simulator's engine noise. The speakers were approximately at the shoulder height of the participants. A subwoofer positioned on the floor beneath the driver's seat provided low-frequency sound.

The simulator was controlled by a steering wheel, an accelerator pedal, and a brake pedal. The simulator PCs registered inputs to these controls and adjusted speed and direction accordingly. The steering wheel was linked to a torque motor, which provided forced-feedback, in order to add realism to the "feel" of the steering.

The driving scenario was developed using STISIM's Scenario Definition Language (SDL). Additional modifications were made to the Test scenario so that the lettering on the CMS displays and the Guide signs could be read when the participants were at a simulated distance of approximately 860 feet (262 meters) from them.

2.3 Experimental Design

As in the Phase I investigation, the two Phase II experiments were conducted back-to-back. In the first experiment, we investigated the effectiveness of a time-critical, site-specific message, while in the second experiment we presented a time-critical, non-site specific CMS message. The design of the two experiments is discussed below.

2.3.1 Experiment One.

The first Phase II experiment examined the effectiveness of a site-specific, time-critical message that was presented at the end of the drive. The message read as follows: "Road Closed/Crash Ahead/Use Thompson Exit." The CMS display presenting this message is shown in Figure 2.3.

Figure 2.3. The site-specific, time-critical message advising participants to use the Thompson exit, as seen on the center display of the simulator.

In this experiment, the participants drove for approximately 20 miles (32.2 km) on a four-lane freeway. As they drove, they encountered a series of nine overpasses. These overpasses occurred at irregular intervals along the freeway. CMS displays were placed on five of the overpasses. During the drive, the participants also encountered two guide signs that provided information on the distances to upcoming exits. Table 2.1 shows the locations, relative to the start of the drive, of the nine overpasses and the guide signs.

Table 2.1. Location of overpasses and guide signs.

Structure	**Distance in miles (and kilometers) from start**
Overpass #1	1.03 miles (1.66 km)
Overpass #2 (with the 1st CMS display)	2.01 miles (3.24 km)
Overpass #3	3.30 miles (5.31 km)
Overpass #4 (with the 2nd CMS display)	5.58 miles (8.98 km)
Overpass #5	9.36 miles (15.07 km)
Overpass #6 (with the 3rd CMS display)	10.58 miles (17.30 km)
Guide Sign #1	12.90 miles (20.76 km)
Overpass #7	13.15 miles (21.16 km)
Overpass #8 (with the 4th CMS display)	15.58 miles (25.08 km)
Guide Sign #2	17.71 miles (28.50 km)
Overpass #9 (with the 5th CMS display)	18.62 miles (29.96 km)

The target message ("Use Thompson Exit") was presented on the fifth and final CMS display. Half of the experimental participants were assigned to Condition A; for them, the first four CMS displays listed in Table 2.1 presented a non-site specific, non-time critical message ("Stay With/Your Vehicle/When Stalled"). An example of the first four CMS displays seen by the participants assigned to Condition A is shown in Figures 2.4.

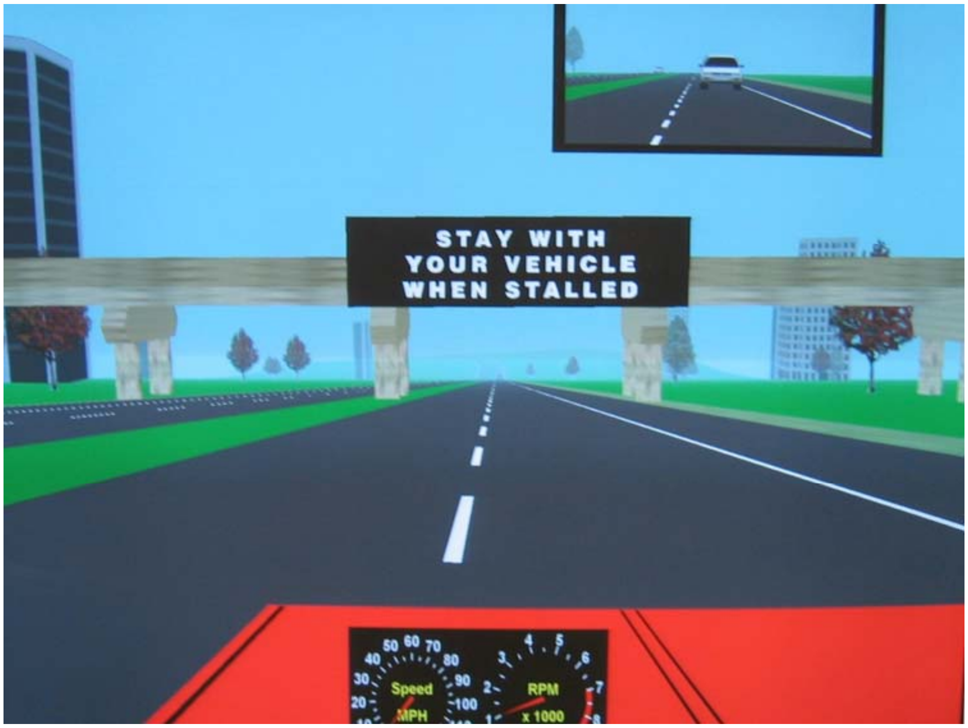

Figure 2.4. The non-site specific, non-time critical message presented on the first four CMS displays to participants assigned to Condition A.

The other half of the participants were assigned to Condition B; for them, the first four CMS displays listed in Table 2.1 were blank. An example of the first four blank CMS displays seen by the participants in Condition B is shown in Figures 2.5.

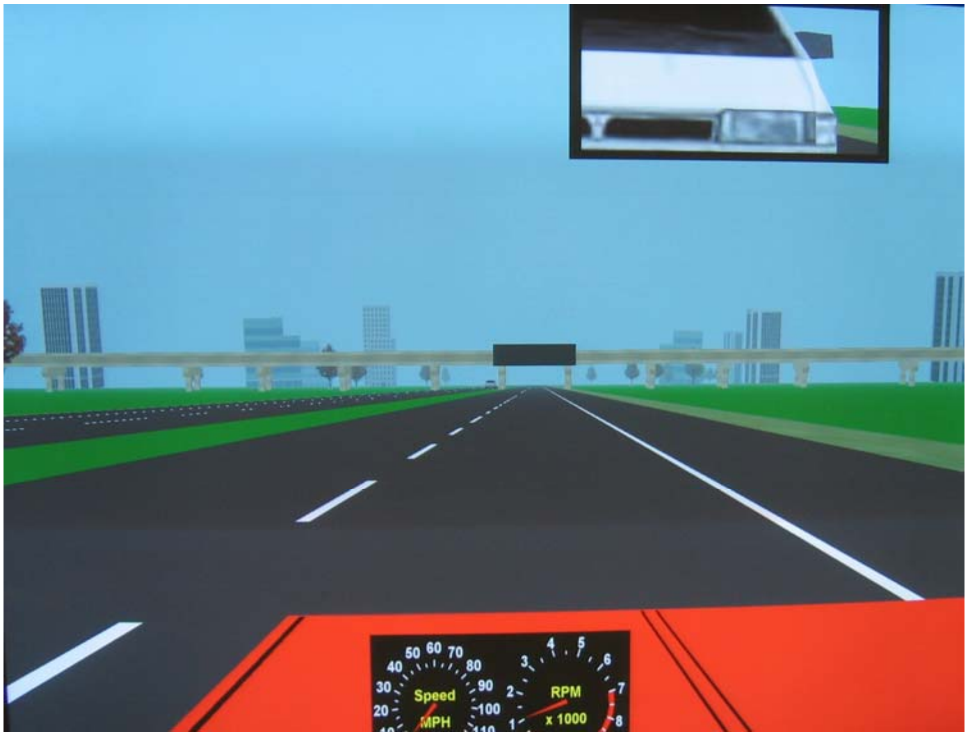

Figure 2.5. The blank CMS display seen on the first four CMS displays by participants assigned to Condition B.

The 60 participants in Condition A, who saw the "Stay With/Your Vehicle/When Stalled" message shown in Figure 2.4, were 20 drivers from the Younger Age Group (18 to 24 year-olds), 20 drivers from the Middle Age Group (32 to 47 year-olds), and 20 drivers from the Older Age Group (55 to 65 year-olds). Also there were ten male and ten female participants in each sub-group of 20 drivers. Similarly, in Condition B, for whom the first four CMS displays were blank (as shown in Figure 2.6, directly above), the 60 participants consisted of 20 drivers (ten male and ten female) from each of the Younger Age, Middle Age, and Older Age Groups. The 120 experimental participants were assigned to Condition A or Condition B using a counterbalanced design.

On the approximately 20-miles (32.2-km) route driven by the participants in both conditions there were two guide signs. The guide signs provided information on the distances to upcoming exits. The first of the two guide signs encountered by the participants is shown in Figure 2.6. [At the second guide sign (not illustrated) the distances to the upcoming exits were all 5 miles less.]

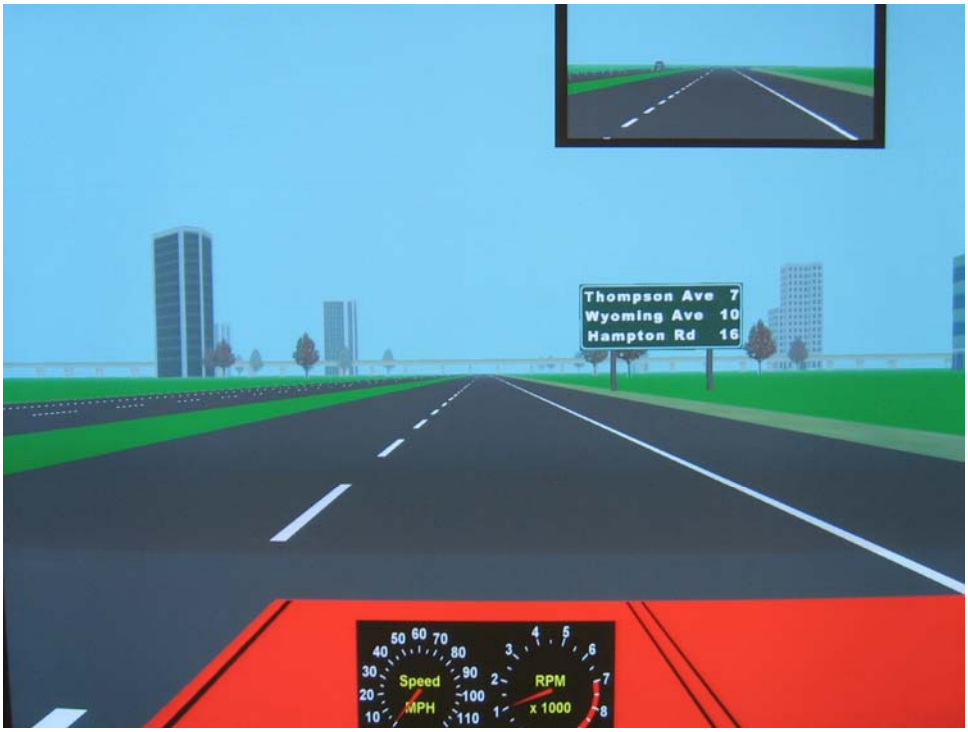

Figure 2.6. The first guide sign on the drive.

2.3.2 Experiment Two.
In the second Phase II experiment, the target message presented at the end of the 20-mile (32.2-km) drive was a time-critical, non-site specific CMS message. The message read "Abducted Child/Tune To/Radio 88.5 FM."

As in the first Phase II experiment, there were two experimental conditions. The participants who were assigned to Condition A for the first experiment were also assigned to Condition A for the second experiment. Similarly, the participants assigned to Condition B for first experiment were also assigned to Condition B for the second experiment. Prior to reaching the target message at the end of the drive, the participants assigned to Condition A encountered four CMS displays that presented the same "Stay With/Your Vehicle/When Stalled" message that was used in the first experiment. And, for the participants assigned to Condition B the first four CMS displays were left blank. The participants in Condition A and Condition B drove approximately 20 miles (32.2 km) on the four-lane freeway, encountering the nine overpasses and two guide signs.

The only difference between the first experiment and the second was that the fifth and final CMS display presented a different target message; in the second experiment the participants saw the time-critical, non-site specific "Abducted Child" message. The CMS display presenting this message is shown in Figure 2.7.

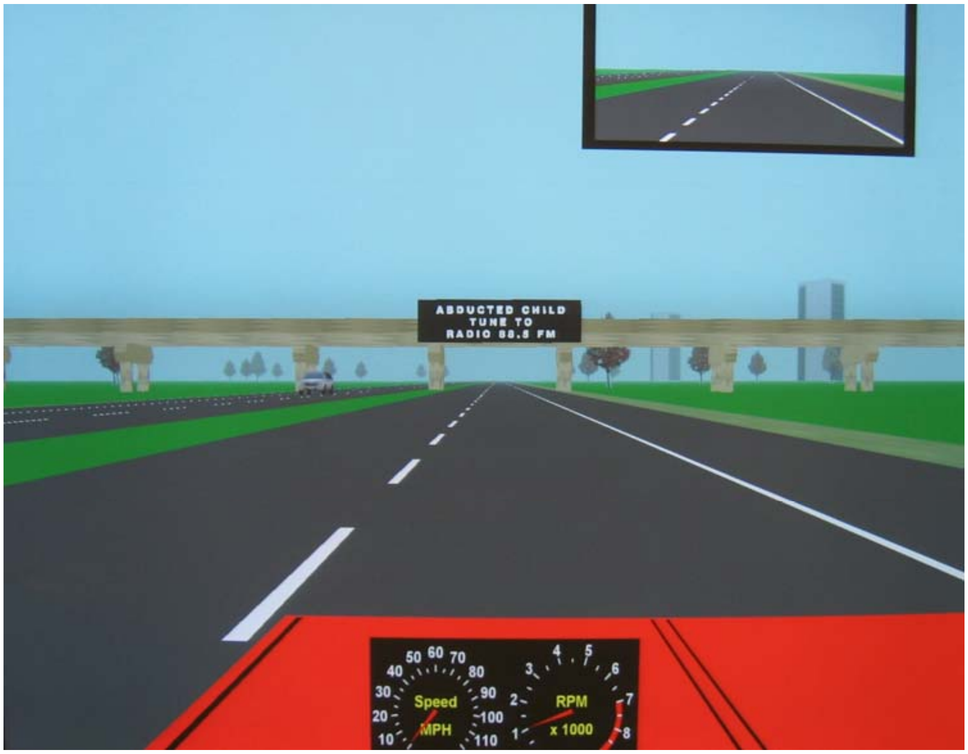

Figure 2.7. The non-site specific, time-critical "Abducted Child" message.

In both experiments, there were low levels of traffic when the participants drove the simulated roadway—so they experienced free flow traffic conditions.

2.4 Procedure

When each participant arrived at the simulator facility, the experimenter examined his or her driver's license to ensure it was valid and to verify the participant's age. Then, the participant read and signed the consent form. The participant was told that the experimental session would last approximately one hour, and that during that time he or she would be asked to drive twice in the driving simulator and, following that, to complete a survey.

The participant took a brief practice drive (of approximately six or seven minutes) on a four-lane divided highway. In the practice drive, the participant was asked to change lanes, to accelerate, and to slow down. After the practice drive, the experimenter answered any questions that the participant had.

The participant was pre-assigned to either Condition A (with the "Stay With/Your Vehicle/When Stalled" message presented on the first four CMS displays) or Condition B (with the first four CMS displays left blank). It should be noted that the participant was not given any information about CMS displays or messages. The only information provided to the participant was that the speed limit on the four-lane divided highway was 55 mph. Then, the participant was asked to, "Please drive as you normally would."

At the end of the first drive, the participant was asked to pull over to the hard shoulder and stop. The experimenter noted whether or not the participant took the Thompson Avenue exit, but did not comment on this to the participant.

The experimenter reset the simulator, and then reminded the participant that the speed limit was 55 mph, and again asked him or her to, "Please drive as you normally would." In the second drive, the participant continued driving until he or she had passed beneath the overpass with the fifth and final CMS display on which the "Abducted Child" message was presented. Immediately after passing beneath this overpass, the participant was asked to move to the hard shoulder and stop. The experimenter switched off the simulator and then asked the participant several predetermined questions.

The participant was asked, "Can you please tell me what was written on the last Message Board over the road?" This was followed by questions about whether the participant could remember any other signs that he or she saw during the drive and what was written on those signs. In addition, if the participant did not take the Thompson Exit at the end of the first drive, he or she was asked, "Did you notice the sign at the end of the first test scenario?" If the participant answered that he or she did see the sign, then the experimenter asked a further question—"What was the reason that you did not take the exit?" [The full text of the questions is presented in Appendix A.]

Then, the participant left the simulator and sat at a desk at the back of the simulator room. There, he or she completed a brief survey. The survey asked the participant to rate the value of travel time information when he or she drives on real-world roads. The survey also included questions about traffic-related information that may be presented on CMSs, and the participant was asked to assess the usefulness of this information. [The full text of the survey is presented in Appendix B.] On completing the survey, the participant was debriefed. The debriefing was as follows:

> "In this study, we are interested in the design of roadways and the signage on those roadways. We would like you to keep the information about this study confidential. Please do not discuss the study with anybody. We do not want anyone who might take part in the study to know anything about it beforehand."

After the debriefing, the participant was paid. The experimental session lasted approximately one hour.

Chapter 3
Results of the Simulation Experiments

The data obtained from the two driving experiments were analyzed. The results of these analyses are presented below.

3.1 The Effectiveness of the Time-Critical, Site-Specific "Use Thompson Exit" Message

3.1.1 Response to the Time-Critical, Site-Specific "Use Thompson Exit" Message
At the end of the first experimental drive, the participants encountered a CMS display, which presented the following time-critical, site-specific, message: "Road Closed/Crash Ahead/Use Thompson Exit."

The participants saw this message after driving 18.6 miles (30.0 km) on the simulated freeway, approximately 1 mile (1.6 km) before they reached the Thompson Exit. Our primary measure of the effectiveness of the message was whether or not the participants took the exit and left the freeway. Table 3.1 presents the number of participants who did take the exit and the number who did not take it but, instead, continued driving on the freeway.

Table 3.1. Number of participants who did and did not take the Thompson Exit.

Outcome	Number of Participants	Percentage of Participants
Took Exit	112	93.3%
Did Not Take Exit	8	6.7%

As Table 3.1 indicates, 112 of the 120 participants (i.e., 93.3%) did take the Thompson Exit. Only eight participants failed to take the exit. These numbers are markedly higher than the numbers of the comparable Phase I experiment, in which the first and second lines of the time-critical, site-specific message read "Crash/At Wyoming Ave" instead of the "Road Closed/Crash Ahead." In the Phase I experiment 67 of the 120 participants (55.8%) took the Thompson Exit.

We used the Chi-Square Test to conduct a statistical comparison of the numbers of participants who did and did not take the Thompson Exit in the Phase I and Phase II experiments. The χ^2 value obtained with the test was 44.51—this value greatly exceeds 10.83, which is the critical value of χ^2 for 1 *df* and $\alpha = 0.001$. The test indicates that the improvement in the number of participants who took the Thompson Exit in Phase II is highly statistically significant.

During the debriefing that occurred after the completion of the second experiment, the eight participants who failed to take the Thompson Exit were asked why they did not take it. Three of the eight participants reported that they did not see the sign—in comparison in the Phase I experiment, 12 participants said they did not see sign. Two of the eight participants saw the "Use Thompson Exit" message but were confused by it—this compares with 19 participants in the Phase I experiment who saw the CMS message but did not understand it. And three participants saw the sign, but did not think that it applied to them—in the Phase I experiment, there were 19 participants who saw the CMS message and thought it did not apply to them.

3.1.2 The Effect of Age, Gender, and Prior Exposure to CMS Messages on the Response to the Time-Critical, Site-Specific "Use Thompson Exit" Message

In the Phase I experiment, we examined the data to determine whether the age and gender of the participants, and whether or not they were exposed to the non-time critical, non-site specific "Stay With/Your Vehicle/When Stalled" message earlier in the drive, affected their response to the time-critical, site-specific, "Use Thompson Exit" message. In Phase I, there were some effects. There was a statistically significant effect of age—participants in the Older Age group were more likely to take the Thompson exit than participants in the Younger Age group. Also, there was a suggestion (at the p =0.0644 level) that prior exposure to the non-time critical, non-site specific message might be associated with fewer participants taking the Thompson exit. But, there was no effect of gender.

In contrast, in Phase II, with much clearer and less ambiguous wording utilized in the "Use Thompson Exit" message, neither age, nor gender, nor prior exposure to Category III messages had any effect on whether or not the participants took the Thompson Exit.

3.2 Speed on the Approach to the Time-Critical, Site-Specific "Use Thompson Exit" Message

3.2.1 Mean Speed on the Approach to the Time-Critical, Site-Specific "Use Thompson Exit" Message

To determine whether there were changes in speed as the participants approached the target message, we divided the final 2,860 feet (871.7 meters) of the approach into three segments—as shown in Table 3.2

Table 3.2. Segment specification (distance from the "Use Thompson Exit" Message).

Segment	Distance from Thompson Exit Message (in feet)	Distance from Thompson Exit Message (in meters)
Segment 1	2,860 feet to 1,860 feet	871.7 meters to 566.9 meters
Segment 2	1,860 feet to 860 feet	566.9 meters to 262.1 meters
Segment 3	860 feet to 0 feet	262.1 meters to 0 meters

In the third segment, when the participants were closest to the target message, it was possible to read the time-critical, site-specific, "Use Thompson Exit" message. This segment was 860-feet (262-meter) to feet (0 meters) from the target message. We compared the driving speed of the participants in this segment of the freeway with their speed in the two 1,000-feet (304.8-meter) segments preceding this segment. As Table 3.2 shows, segment 1 was between 2,860 feet (871.7) meters and 1,860 feet (566.9 meters) from the target message, and segment 2 was between 1,860 feet (566.9 meters) and 860 feet (262.1 meters) from the target message.

To determine whether there were differences in the mean speeds at which the participants drove through each of the three segments listed on the approach to the target message, we conducted a four-way Analysis of Variance (ANOVA). The ANOVA examined the main effects of (1) the gender of the participants; (2) the age of the participants; (3) prior CMS exposure—i.e., whether or not the participants were exposed to the non-time critical, non-site specific message on the first four CMS displays; and (4) the freeway segments on the approach to the target message. Table 3.3 presents a summary of the results of this ANOVA.

Table 3.3. Summary of the ANOVA examining the effects on mean speed of gender, age, prior exposure to CMS messages, and freeway segments.

Source of variation	**Degrees of freedom**	**Sum of Squares**	**Variance estimate**	**F-Value**	**p-value**
Gender (G)	1	49.469	49.469	0.678	*ns*
Age (A)	2	1,109.839	554.92	7.609	0.0008
Prior Exposure (E)	1	7.972	7.972	0.109	*ns*
G x A interaction	2	74.124	37.062	0.508	*ns*
G x E interaction	1	9.348	9.348	0.128	*ns*
A x E interaction	2	5.440	2.720	0.037	*ns*
G x A x E interaction	2	290.898	145.449	1,994	*ns*
Error Term 1 (Subjects within Groups)	108	7,876.371	72.929		
Segment (S)	2	25.794	12.897	3.721	0.0258
S x G interaction	2	20.682	10.341	2.983	*ns*
S x A interaction	4	8.274	2.069	0.597	*ns*
S x E interaction	2	15.671	7.836	2.261	*ns*
S x G x A	4	5.237	1.309	0.378	*ns*
S x G x E	2	9.224	4.612	1.331	*ns*
S x A x E	4	0.545	0.136	0.039	*ns*
S x G x A x E	4	5.771	1.443	0.416	*ns*
Error Term 2 (S x Subjects within Groups)	216	748.681	3.466		

Table 3.3 indicates that there were two statistically significant main effects. The age of the participants and the freeway segments on the approach to the target message both affected mean speed. The effect of the age of the participants was significant at the p=0.0008 level and the effect of the freeway segments was significant at the p=0.0258 level. Both of these main effects are illustrated in Figure 3.1 below.

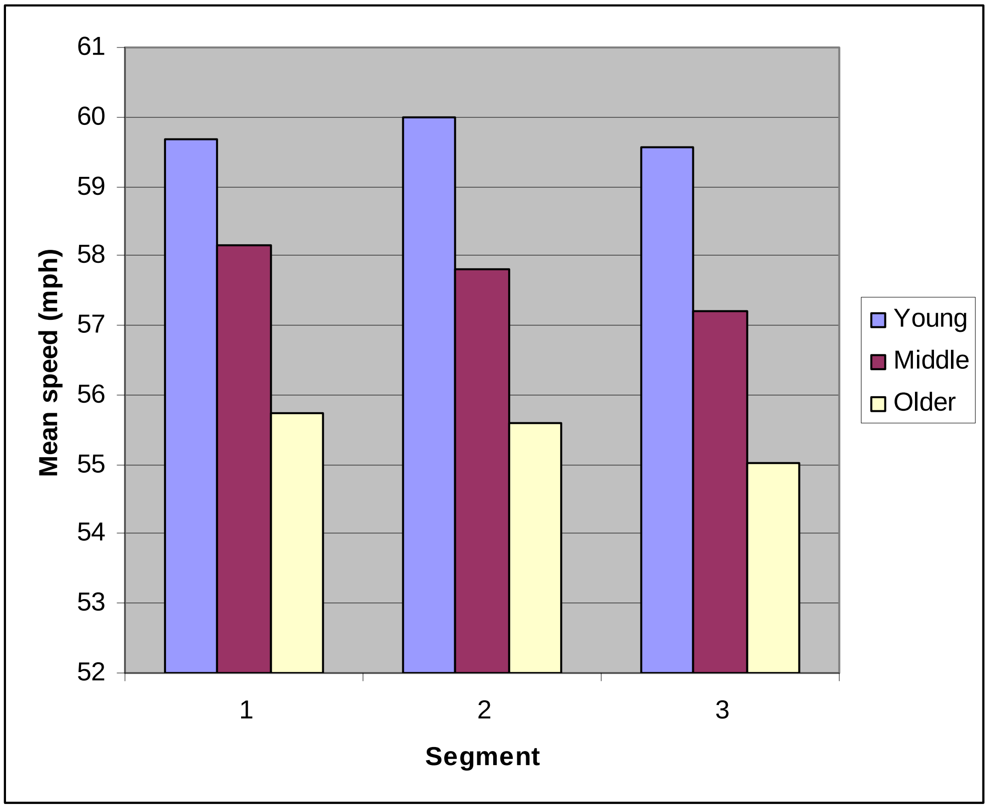

Figure 3.1. Mean speed for each age group in each freeway segment on the approach to the “Use Thomson Exit” CMS message.

The effect of age on mean driving speed can be seen in Figure 3.1. In all three freeway segments, the mean speed for the participants in the Younger Age Group was approximately 2 mph (3.2 km/h) faster than the mean speed for the participants in the Middle Age Group. In turn, the mean speed for the Middle Age Group participants was approximately 2.3 mph (3.7 km/h) faster than the mean speed of the participants in the Older Age Group.

Figure 3.1 also shows the effect of freeway segments on mean driving speed. Examination of Figure 3 shows that in segment 3, when the participants were between 860 feet (262.1 meters) and 0 feet (0 meters) from the “Use Thompson Exit” message, the mean speed was slower for all three age groups than it was in segments 1 and 2. In segments 1 and 2, the mean speeds of the three participants groups were 59.8 mph (96.3 km/h), 58.0 mph (93.3 km/h), 55.7 mph (89.6 km/h), for the Younger, Middle, and Older Age Groups, respectively. The average reductions in speed from the first two segments to the third segment were 0.28 mph (0.44 km/h), 0.78 mph (1.25 km/h) and 0.64 mph (1.03 km/h) for the participants in the Younger, Middle, and the Older Age Groups, respectively. While these reductions in mean speed were statistically significant, they were relatively small.

3.2.2 Speed Reductions on the Approach to the Time-Critical, Site-Specific, "Use Thompson Exit" Message

Because mean speed reductions do not reveal the extent to which individual drivers slow down, we examined the speeds of individual participants in more detail. We focused on the speed of each participant in segment 2, when they were between 1,860 feet (566.9 meters) and 860 feet (262.1 meters) from the target message, and segment 3, when they were between 860 feet (262.1 meters) and 0 feet (0 meters) from the target message and were able to read the target message.

We found that there were 31 participants who reduced speed by 2 mph (3.2 km/h) or more between segment 2 and segment 3. The amount by which these participants reduced speed is shown in Table 3.4. [For comparison purposes, the table also shows speed reduction data from the equivalent Phase I experiment.]

Table 3.4. Speed reductions approaching the "Use Thompson Exit" message in Phase II and Phase I.

Speed Range	Number of Participants in Range in Phase II	Cumulative Number of Participants in Phase II	Cumulative Number of Participants in Phase I
-12 to -13 mph (-19.3 to -20.9 km/h)	0	0	2
-11 to -12 mph (-17.7 to -19.3 km/h)	0	0	3
-10 to -11 mph (-16.1 to -17.7 km/h)	0	0	4
-9 to -10 mph (-14.5 to -16.1 km/h)	0	0	4
-8 to -9 mph (-12.9 to -14.5 km/h)	1	1	4
-7 to -8 mph (-11.3 to -12.9 km/h)	2	3	6
-6 to -7 mph (-9.7 to -11.3 km/h)	1	4	6
-5 to -6 mph (-8.0 to -9.7 km/h)	2	6	6
-4 to -5 mph (-6.4 to -8.0 km/h)	4	10	10
-3 to -4 mph (-4.8 to -6.4 km/h)	5	15	10
-2 to -3 mph (-3.2 to -4.8 km/h)	16	31	16

Table 3.4 presents the extent of the reductions in speed for the Phase II participants who slowed down by 2 mph (3.2 km/h) or more as they approached the "Use Thompson Exit" message. Thirty-one Phase II participants reduced speed by between 2 mph (3.2 km/h) and 9 mph (14.5 km/h) as they drove from segment 2 to segment 3. Table 3.4 also shows the cumulative speed reduction numbers—for example, while only 3 out 120 participants slowed down by 7 mph (11.3 km/h) or more, 15 of the 120 participants slowed down by 3 mph (4.8 km/h) or more.

The table also presents the cumulative speed reduction numbers for the first Phase I experiment—in Phase I, 16 of the 120 participants reduced speed by 2 mph (3.2 km/h) or more. For greater speed reductions of 5 mph (8.0 km/h) or more, 6 of the 120 participants (5.0%) were involved in both Phase II and Phase I. However, the table also shows that while there were four participants who reduced speed by 9 mph (14.5 km/h) or more in Phase I, there were none who reduced speed by this much in Phase II.

We considered the gender and age of the 31 Phase II participants who reduced speed by 2 mph (3.2 km/h) or more on the approach to the "Use Thompson Exit" message. Neither gender nor age was related to whether or not the participants reduced speed by 2 mph (3.2 km/h) or more. Also, whether or not the participants were exposed to CMS messages earlier in the drive was not related to speed reductions on the approach to the target message.

If the speed reduction data shown in Table 3.4, when the participants were driving in free flow traffic conditions, reflect real-world driving behavior, then it is likely that some drivers in free flow conditions reduce speed as they approach CMS messages. In non free flow traffic conditions, traffic speeds are typically slower than they are with free flow conditions—and when the traffic is already moving at slower speeds, individual drivers are less likely to reduce speed further to read CMS messages.

3.3 The Effectiveness of the Time-Critical, Non-Site Specific, "Abducted Child" Message

3.3.1 Response to the Time-Critical, Non-Site Specific "Abducted Child" Message

At the end of the second Phase II experiment, each participant encountered a CMS display that presented the following time-critical, non-site specific message: "Abducted Child/Tune To/Radio 88.5 FM."

This message was displayed on an overpass located 18.6 miles (30.0 km) from the start of the drive. Immediately after passing beneath this overpass, each participant was asked to pull over and stop. Then, he or she was asked, "Can you please tell me what was written on the last Message Board over the road?"

The "Abducted Child" message that was displayed in the second Phase II experiment was relatively simple. For anyone who wished to follow up on the message—by tuning to the appropriate radio station—it would be sufficient to remember the following information: "Abducted Child Tune to 88.5" (the other terms in the message "Radio" and "FM" are essentially redundant). Eighty-six of the 120 participants (i.e., 71.7%) in the second Phase II experiment remembered sufficient information to enable them tune into 88.5 FM. [Please note: one of these 86 participants reported that the message said "Missing Child" rather than "Abducted Child." Also, for five of these 86 participants the radio frequency was not exactly correct—two of these five participants reported the frequency as "88;" one reported the frequency as "86 or 88;" another reported it as "88.8;" and the fifth participant reported it as "88.9." As a practical matter, the radio frequency reported by all five of these participants is so close to 88.5 that if they attempted to tune in they would be successful tuning in to 88.5 FM—for this reason their responses were considered to be correct. Also, it should be noted that other participants reported the following *incorrect* radio frequencies—"6.3," "96," "98," "98.5," "98.6," "98.8," "98.9," "720," and "1400."]

The equivalent "AMBER Alert" message investigated in the Phase I study was far more complex than the "Abducted Child" message. In the second Phase I experiment, ten of the 120 participants (i.e., 8/3%) recalled that the message was an AMBER Alert, as well as some vehicle information and at least five of the six letters and numbers in the license plate number. Only two of the 120 participants recalled all of the information on the CMS correctly. The improvement in the number of participants who obtained sufficient information to respond to the message if they chose to do so—from 10 participants who recalled the "AMBER Alert" to 86 participants who recalled the "Abducted Child" message—is very impressive.

We examined the Phase II data to determine whether they were affected by the age and gender of the participants, and whether or not they were exposed to the "Stay With/Your Vehicle/When Stalled." None of these variables had a significant effect. With regard to age, 34 of the 86 participants were in the Younger Age Group, 26 in the Middle Age Group, and 26 in the Older Group. When the Chi-Square Test was used to compare these numbers, we obtained a χ^2 value of 5.25—this does not exceed 5.99, the critical value of χ^2 for 2 *df* and $\alpha = 0.05$. With regard to gender, 47 of the 86 participants were female, and 39 were male. Again, the result of conducting a Chi-Square Test indicated this difference was not statistically significant. And, finally, with regard to whether or not the participants were exposed to the "Stay With/Your Vehicle/When Stalled" message before they encountered the target message, the numbers, in each category were identical—43 of the 86 participants were exposed to the message, and 43 were not.

3.3.2 Knowing the Meaning of the Term "Abducted Child"
In the Phase I study, after the participants completed both experiments, one question they were asked was, "What does 'AMBER Alert' mean?" Responses to this question were obtained from 114 of the 120 participants. Thirty-two of these 114 participants (28%) did not know what "AMBER Alert" meant (although there were some inventive guesses—e.g., that the alert might refer to terrorist activity).

In Phase II, the participants were asked an equivalent question, "What does 'Abducted Child' mean?" All 120 Phase II participants knew what "Abducted Child" meant.

3.3.3 Likely Action on Seeing an "Abducted Child" Message
The Phase II participants were also asked, "What would you do if you saw an 'Abducted Child' sign?" The responses can be categorized as follows.

- 61/120 (50.8%)—would tune in to the radio station.
- 13 (10.8%)—would probably tune in.
- 9 (7.5%)—might or maybe would tune in.
- 22 (18.3%)—would pay attention.
- 15 (12.5%)—would take no action or probably would take no action.

We examined the 83 participants in the first three categories—i.e., those who said they would tune in, probably would tune in, or might or maybe would tune in to the radio station—to determine whether there were any effects of the age and gender of the participants, and whether or not they were exposed to the "Stay With/Your Vehicle/When Stalled" message before they encountered the "Abducted Child" message. None of these variables had a significant effect. With regard to age, 30 of the 83 participants were in the Younger Age Group, 31 in the Middle Age Group, and 22 in the Older Age Group. The Chi-Square Test performed on these data, yielded a χ^2 value of 5.71, which does not exceed 5.99, the critical value of χ^2 for 2 *df* and $\alpha =$

0.05. With regard to gender, 45 of the 83 participants were female, and 38 were male. Again, we conducted a Chi-Square Test—the resultant χ^2 value of 1.91 doe not exceed 3.84, the critical value of χ^2 for 1 *df* and $\alpha = 0.05$. And, with regard to whether or not the participants were exposed to the “Stay With/Your Vehicle/When Stalled” message before encountering the “Abducted Child” message, the numbers in each category were virtually identical—42 of the 83 participants were exposed to this message, and 41 were not.

3.4 Speed on the Approach to the Time-Critical, Non-Site Specific, “Abducted Child” Message

3.4.1 Mean Speed on the Approach to the Time-Critical, Non-Site Specific “Abducted Child” Message

It was possible to read the target message, the “Abducted Child/Tune To/Radio 88.5 FM” message, approximately 860 feet (262.1 meters) from the CMS display on which it was presented. Again, we determined the mean speed at which the participants drove in this 860-feet (262-meter) freeway segment, and their mean speed in the previous two 1,000-foot (304.8-meter) segments. [The segments are specified in Table 3.2, above.]

We conducted a four-way ANOVA to determine whether there were differences in the mean speeds at which the participants drove through each of the three segments on the approach to the target message. The ANOVA analyzed the effect of (1) the gender of the participants; (2) the age of the participants; (3) prior CMS exposure—i.e., whether or not the participants were exposed to the non-time critical, non-site specific “Stay With/Your Vehicle/When Stalled” message before encountering the “Abducted Child” message; and (4) the three freeway segments on the approach to the “Abducted Child” message. A summary of results of this four-way ANOVA is presented in Table 3.5.

Table 3.5. Summary of the ANOVA of the effects of gender, age, prior exposure to CMS messages and segment on mean speed.

Source of variation	**Degrees of freedom**	**Sum of Squares**	**Variance estimate**	**F-Value**	**p-value**
Gender (G)	1	149.408	149.408	1.327	*ns*
Age (A)	2	1,918.162	959.081	8.516	0.0004
Prior Exposure (E)	1	3.238	3.238	0.029	*ns*
G x A interaction	2	99.855	49.927	0.443	*ns*
G x E interaction	1	4.303	4.303	0.038	*ns*
A x E interaction	2	88.687	44.343	0.394	*ns*
G x A x E interaction	2	54.468	27.234	0.242	*ns*
Error Term 1 (Subjects within Groups)	108	12,162.493	112.616		
Segment (S)	2	18.665	9.333	1.396	*ns*
S x G interaction	2	37.048	18.524	2.772	*ns*
S x A interaction	4	27.652	6.913	1.034	*ns*
S x E interaction	2	0.811	0.406	0.061	*ns*
S x G x A	4	75.858	18.945	2.838	0.0253
S x G x E	2	4.528	2.264	0.339	*ns*
S x A x E	4	24.502	6.125	0.917	*ns*
S x G x A x E	4	12.450	3.112	0.466	*ns*
Error Term 2 (S x Subjects within Groups)	216	1,443.496	6.683		

Table 3.5 indicates that there were two statistically significant effects. The age of the participants was significant at the p=0.0004 level. Also, the three-way interaction between segments, the gender of the participants, and the age of the participants was significant at the p=0.0253 level. The three-way interaction is illustrated in Figure 3.2. The figure is complicated—there are six columns for each of the three segments on the approach to the "Abducted Child" message. And for each segment, there is one column for each of the six combinations of gender and age. In each block of six columns, the first two columns present the mean speeds for the participants in the Young Male Group and the Young Female Group, the third and fourth columns present the mean speeds for the participants in the Middle Age Male Group and the Middle Age Female Group, while the fifth and sixth columns present the mean speeds for the participants in the Older Male Group and the Older Female Group.

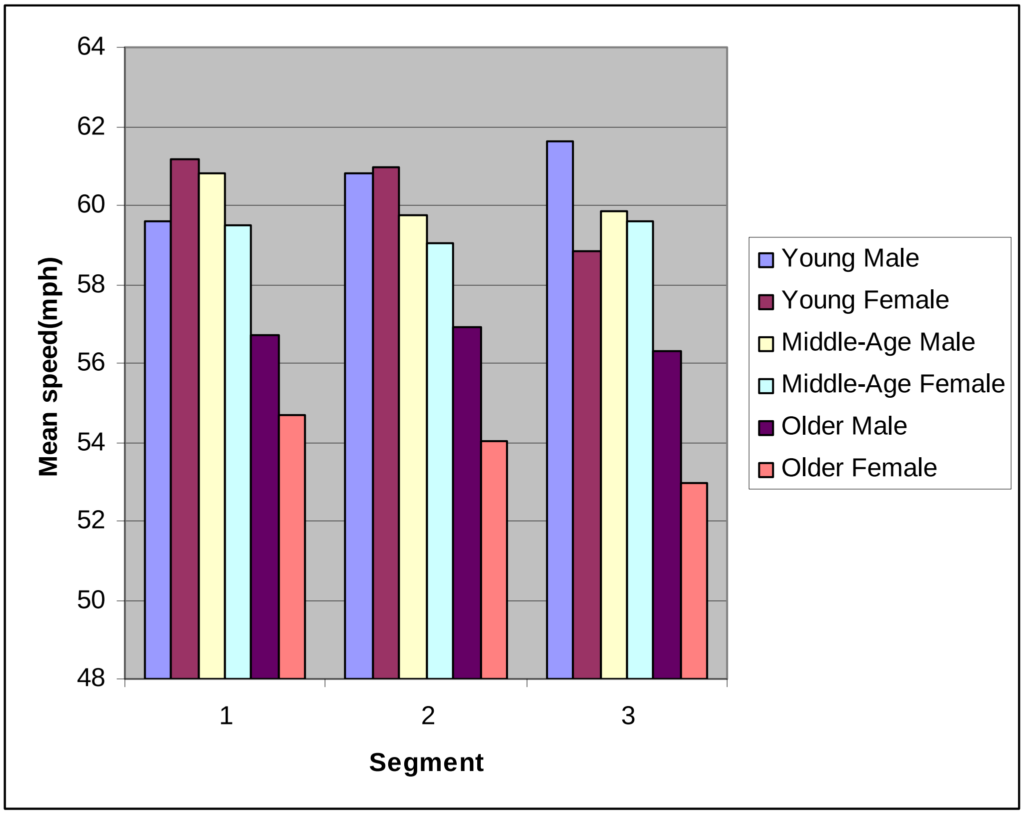

Figure 3.2. Mean speed for each age and gender group in each segment on the approach to the "Abducted Child" CMS message.

The various effects shown in Figure 3.2 are described in the following five sub-sections.

3.4.1.1 Effect of age on mean speed. In Figure 3.2, the mean speeds for the first four columns for all three segments—i.e., the mean speeds for the Younger Males, the Younger Females, the Middle Age Males and the Middle Age Females—are clearly faster than the mean speeds for the last two columns—i.e., for the Older Males and the Older Females.

3.4.1.2 Effect of gender with older participants. Also in Figure 3.2, the mean speeds for the fifth column for all three segments—i.e., the mean speeds for the Older Males—are clearly faster than the mean speeds for the sixth column—i.e., the mean speeds for the Older Female participants.

3.4.1.3 Effect of segments with older female participants. Figure 3.2 also shows that the mean speeds for the sixth column (i.e., for the participants in the Older Female Group) decrease from the first to the second to the third segment.

3.4.1.4 Effect of gender with middle-age drivers. Next, by focusing on the third and fourth columns for each segment in Figure 3.2, it can be seen that in each case the mean speeds for the third column (i.e., for the Middle Age Males) are faster than the mean speeds for the fourth column (i.e., for the Middle Age Females).

3.4.1.5 Effect of gender with younger drivers. Finally, by considering the first two columns for each segment in Figure 3.2, it can be seen that the mean speeds in the first column (i.e., for the Younger Males) increase from the first to the second to the third segment while, in contrast, the mean speeds in the second column (i.e., for the Younger Females) decrease from the first to the second to the third segment.

These interaction effects are complex, and it is difficult to determine their relevance to real-world driving—except for the obvious fact that the drivers in the Older Age Group tend to drive at slower speeds than the drivers in the Younger and Middle Age Groups.

3.4.2 Speed Reductions on the Approach to the Time-Critical, Non-Site Specific "Abducted Child" Message

Because mean speed reductions do not reveal the extent to which individual drivers slow down, we examined the speeds of individual participants in more detail. We compared the speed of each participant in segment 2, when he or she was between 1,860 feet (566.9 meters) and 860 feet (262.1 meters) from the "Abducted Child" message, with his or her speed in segment 3, when he or she was able to read the target message and was between 860 feet (262.1 meters) and 0 feet (0 meters) from it.

There were 28 participants who reduced speed by 2 mph (3.2 km/h) or more between segment 2 and segment 3 on the approach to the "Abducted Child" message. The amount by which these participants reduced speed is shown in Table 3.6. . [For comparison purposes, the table also shows speed reduction data from the second Phase I experiment.]

Table 3.6. Speed reductions approaching the "Abducted Child" message in Phase II and the "AMBER Alert" in Phase I.

Range	Number of Participants in Range in Phase II	Cumulative Number of Participants in Phase II	Cumulative Number of Participants in Phase I
-13 to -14 mph (-20.9 to -22.5 km/h)	1	1	1
-12 to -13 mph (-19.3 to -20.9 km/h)	0	1	1
-11 to -12 mph (-17.7 to -19.3 km/h)	0	1	1
-10 to -11 mph (-16.1 to -17.7 km/h)	0	1	2
-9 to -10 mph (-14.5 to -16.1 km/h)	2	3	2
-8 to -9 mph (-12.9 to -14.5 km/h)	0	3	4
-7 to -8 mph (-11.3 to -12.9 km/h)	3	6	6
-6 to -7 mph (-9.7 to -11.3 km/h)	3	9	11
-5 to -6 mph (-8.0 to -9.7 km/h)	1	10	13
-4 to -5 mph (-6.4 to -8.0 km/h)	4	14	20
-3 to -4 mph (-4.8 to -6.4 km/h)	8	22	22
-2 to -3 mph (-3.2 to -4.8 km/h)	6	28	26

As Table 3.6 shows, 28 of the 120 participants in Phase II reduced speed by 2 mph (3.2 km/h) or more on the approach to the "Abducted Child" message. The table also shows the cumulative speed reduction numbers. For comparison purposes, the table also shows cumulative numbers for the equivalent Phase I experiment. In Phase I, 26 of the 120 participants reduced speed by 2 mph (3.2 km/h) or more on the approach to the “AMBER Alert” message used in that study. Examination of the two columns presenting the cumulative speed reduction numbers for Phase II and Phase I reveals that the numbers of participants who reduced speed on the approach to the target message were similar, in all speed ranges.

We examined whether there were any effects of the gender and age of the participants, and whether or not they were exposed to CMS messages earlier in the drive, on the numbers of participants who reduced speed on the approach to the “Abducted Child” message. In each case, the Chi-Square Test did not indicate any statistically significant differences.

As with the speed reduction data obtained in the first Phase II experiment, the speed reduction data presented in Table 3.6 were obtained when the participants were driving in free flow traffic conditions. If these data are representative of real-world driving behavior, then it is likely that some drivers in free flow conditions do slow down as they approach CMS messages. This may not be the case when traffic is congested—then traffic speeds are typically slower. When traffic is already moving at slower speeds, individual drivers are less likely to reduce speed still further in order to read CMS messages. However, with highly complex CMS messages it is more likely that some drivers will reduce speed whether they are in free flow traffic or not.

Chapter 4
Survey Results

After completing the first and second Phase II experiments and answering the questions related to driving in the simulator, the 120 participants were asked to complete a survey. This survey consisted of ten questions that explored the attitudes of the participants to CMS messages. The first three questions in the survey explored attitudes to travel time information. The fourth, fifth, and sixth questions dealt with information about traffic problems. The seventh and eighth questions were related to safety messages. And, the final two questions were concerned with information about road maintenance.

4.1 Travel Time Information

The first question in the survey asked, “When you are driving on Metro Freeways, have you seen message boards that give travel time information—i.e., messages that tell you how much time it will take to get to a particular location or to a freeway?” The responses to this question were:

- 112 (93.3%)—had seen message boards that give travel time information on the Metro Freeways.
- 8 (6.7%)—had not seen these messages.

For the second survey question, the participants were asked to respond by marking a scale which ranged from 1 to 7, where “1” meant “Not at all useful” and “7” meant “Very useful.” An example of such a scale is shown below.

Not at all useful 1 2 3 4 5 6 7 Very useful

The second question asked the participants, “How useful to you is travel time information?” One hundred thirteen of the Phase II participants responded to this question. The distribution of these 113 responses is shown in Figure 4.1.

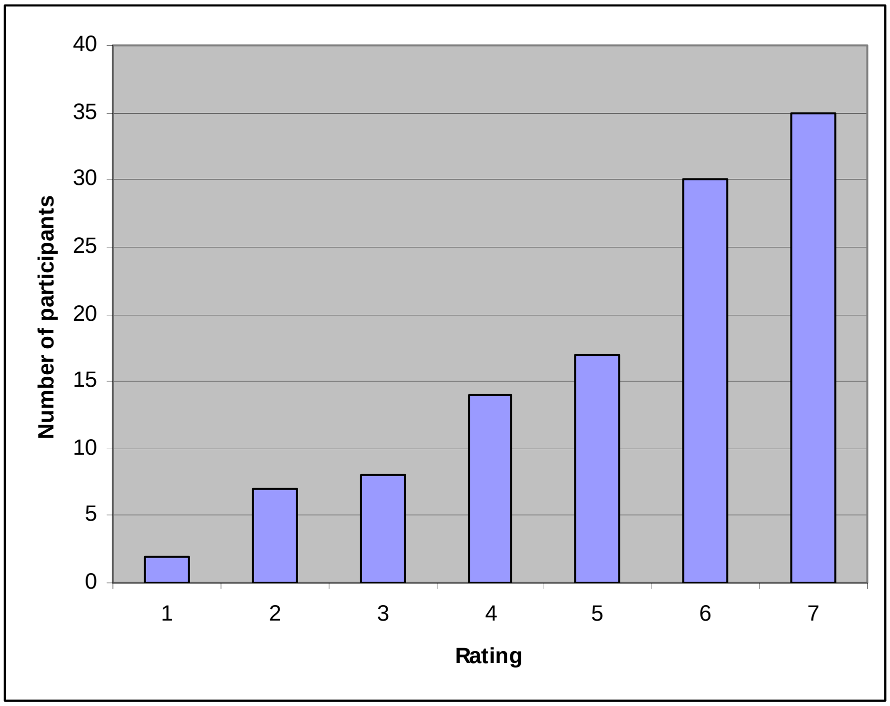

Figure 4.1. Distribution of responses rating the usefulness of travel time information to the participants.

As Figure 4.1 shows, the distribution of responses was positively skewed (the mean value was 5.38, and the standard deviation was 1.63). Sixty-three of the 113 participants (55.8%) who responded gave high ratings of six or seven. The responses to this question indicate that there is a high approval rating for the provision of travel time information on Metro Freeway CMS displays.

The third question on the survey, like the second, asked the participants to respond by marking a scale which ranged from 1 to 7—although in this case "1" meant "Greatly increases my stress level" and "7" meant "Greatly reduces my stress level."

The third question was, "Does travel time information affect your stress level when you are driving?" As with the second question, 113 of the participants responded to this question. The way in which these 113 responses were distributed is shown in Figure 4.2.

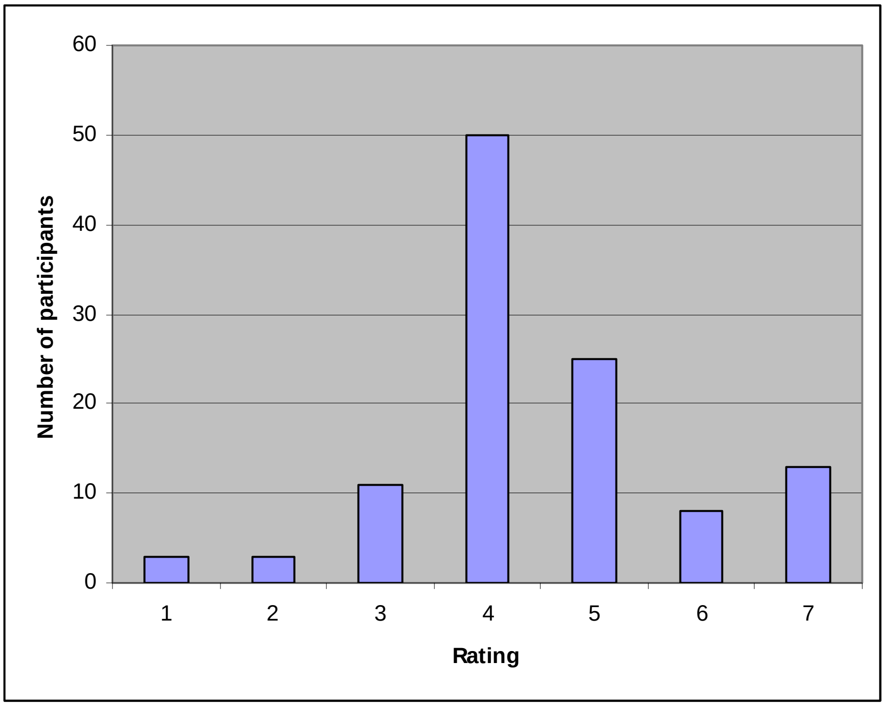

Figure 4.2. Distribution of responses rating the effect of travel time information on the stress level of the participants.

As Figure 4.2 shows, the responses to the third question were spread across the scale, with the median at 4, the neutral point. The mean value of the responses was 4.38, and the standard deviation was 1.54. This result indicates that on average the Phase II participants reported that the provision of travel time information on Metro Freeway CMS displays had little effect on their stress level—although there is an indication that it may reduce their stress level a little.

4.2 Information about Traffic Problems

The fourth, fifth, and sixth questions on the survey dealt with information about traffic problems. The fourth question was, "When you are driving on Metro Freeways have you seen message boards that give information about traffic problems ahead that could affect traffic speed—i.e., messages tell you that there is a 'Crash Ahead' or 'Congestion Ahead' or 'Road Work Ahead' or a 'Stalled Vehicle Ahead'?" The responses to this question were:

- 112 (93.3%)—had seen message boards that present information about traffic problems ahead.
- 8 (6.7%)—had not seen these messages.

For the fifth survey question, the participants were asked to respond by marking a scale which ranged from 1 to 7, where "1" meant "Not at all useful" and "7" meant "Very useful."

Specifically, the fifth question asked the participants, “How useful to you is information about traffic problems?” All 120 of the Phase II participants responded to this question. The distribution of these responses is presented in Figure 4.3 below.

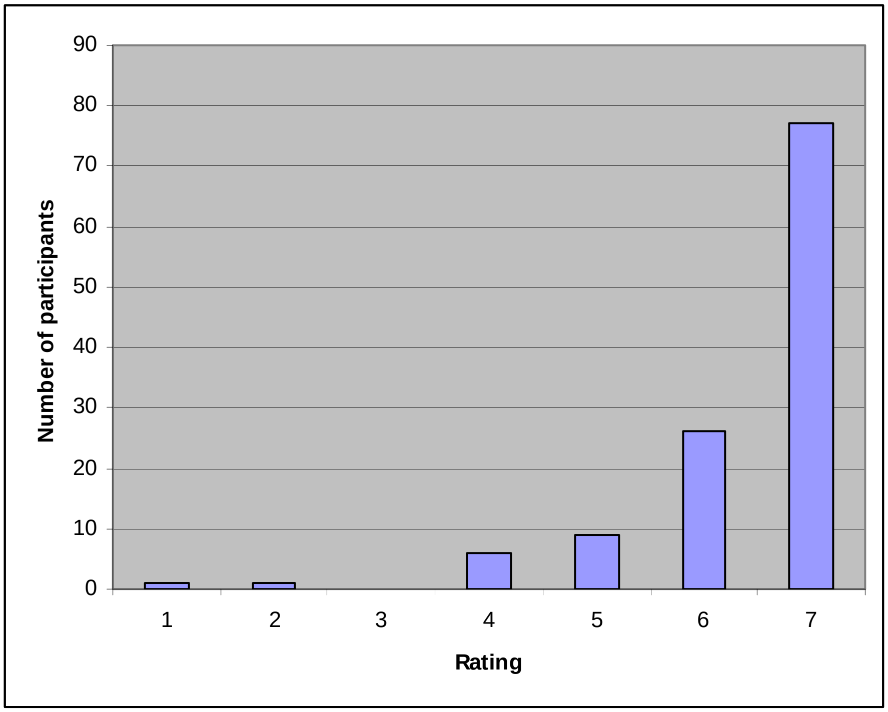

Figure 4.3. Distribution of responses rating the usefulness of information about traffic problems to the participants.

Figure 4.3 shows the distribution of responses that rated the value of information about traffic problems ahead was highly positively skewed—77 of the participants (64.2%) gave the highest rating, and another 26 (21.7%) gave the second highest rating (the mean value was 6.39, and the standard deviation was 0.86). With 103 of 120 participants (85.8%) giving very high ratings in response to this question, it is clear that there is a very high approval rating for the provision of information about traffic problems ahead that could affect traffic speed on Metro Freeway CMS displays.

The sixth survey question also asked the participants to respond by marking a scale which ranged from 1 to 7. In this case “1” meant “Greatly increases my stress level” and “7” meant “Greatly reduces my stress level.”

The sixth question was, “Does information about traffic problems affect your stress level when you are driving?” All 120 of the Phase II participants responded to this question. The distribution of these responses is shown in Figure 4.4.

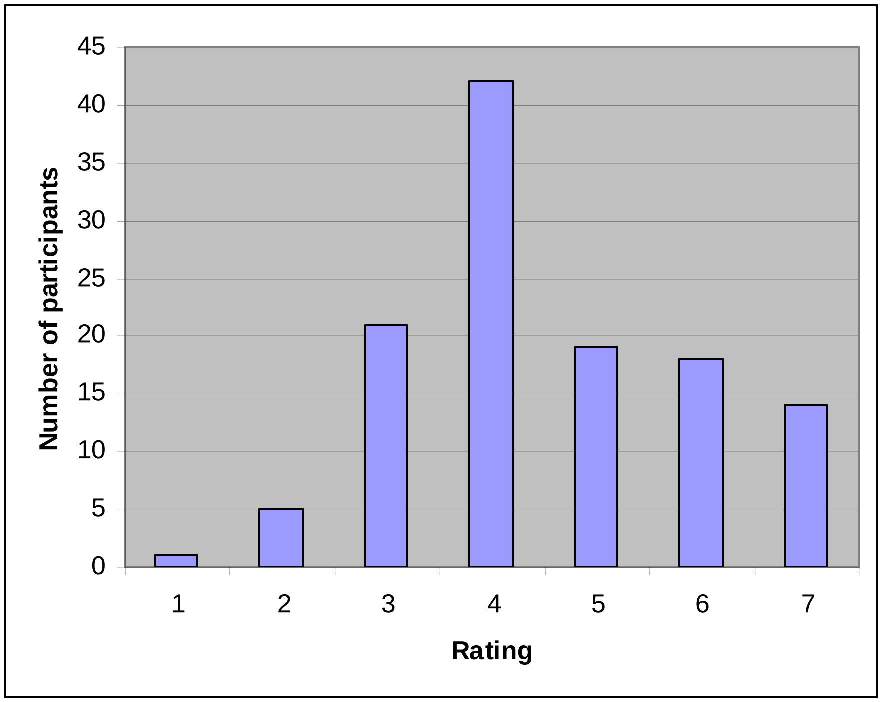

Figure 4.4. Distribution of responses rating the effect that information about traffic problems has on the stress level of the participants.

Figure 4.4 shows that the responses to the sixth question were spread across the scale, with 4, the neutral point, receiving the most ratings. The mean value of the ratings was 4.51, and the standard deviation was 1.48. These results indicate that on average the Phase II participants reported that the provision of information regarding traffic problems on Metro Freeway CMS displays was neutral to slightly positive with regard to their stress level—with an indication it may reduce stress levels a little.

4.3 Safety Messages

The seventh and eighth questions in the survey dealt with safety messages on CMS displays. The seventh question was, "When you are driving on Metro Freeways have you seen message boards that give safety messages—like 'Buckle Up' or 'Don't Drive Drowsy' or 'Don't Drink and Drive'?" The responses to this question were:

- 108 (90%)—had seen message boards that presented safety messages.
- 12 (10%)—had not seen these messages.

For the eighth survey question, the participants were asked to respond by marking a scale which ranged from 1 to 7, where "1" meant "Not at all useful" and "7" meant "Very useful."

The eighth question asked the participants, "How useful to you are safety messages?" There were 108 participants who responded to this question—the distribution of these 108 responses is presented in Figure 4.5.

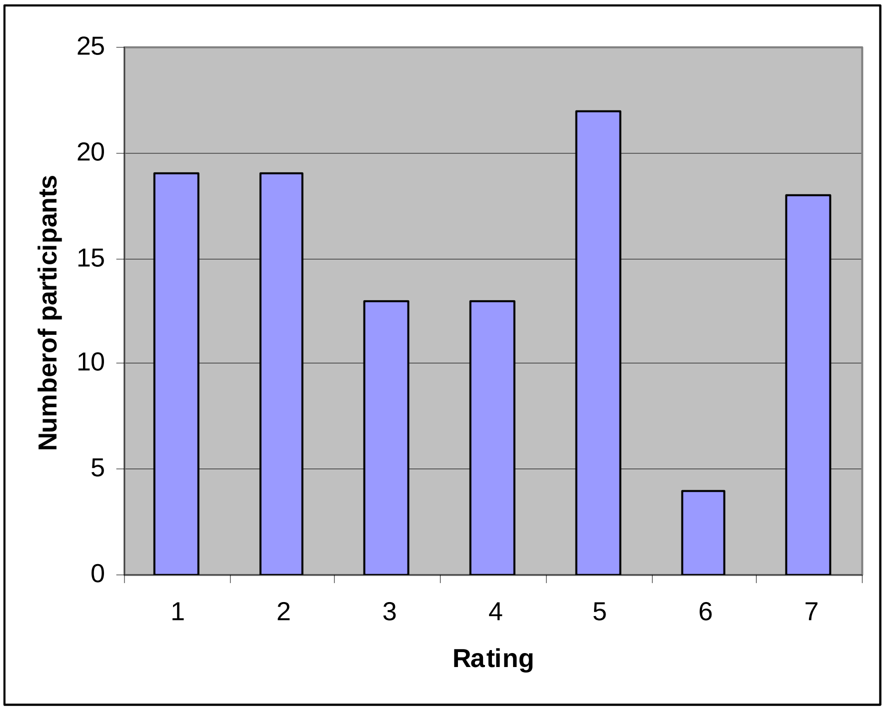

Figure 4.5. Distribution of responses rating the usefulness of safety messages to the participants.

Figure 4.5 shows that there was little agreement among the participants responding to the sixth question. The ratings were spread all over the scale—19/108 (17.6%) gave a rating of "1"—indicating that for them safety messages are not useful at all; and another 19/108 (17.6) gave a rating of "2"—indicating that safety messages are not useful. In contrast, 18/108 (16.7%) gave a rating of "7"—for them safety messages are very useful. And 22/108 (20.4%) gave a rating of "5"—suggesting that for them safety messages are somewhat useful. It is because of the divided nature of the ratings to this question that the standard deviation of the scores was relatively high—it was 2.11 (and the mean of the ratings was 3.39). These results indicate that, with regard to the usefulness of safety messages, the response of the Phase II participants is mixed and, on average, slightly negative.

4.4 Information about Roadway Maintenance Schedules

The last two survey questions in the survey dealt with information about roadway maintenance schedules. The ninth question asked, "When you are driving on Metro Freeways have you seen message boards that give information about roadway maintenance schedules—like 'Road Closed Thru June 1' or 'Road Closed June 19 Thru July 25'?" The responses to this question were:

- 115 (95.8%)—had seen message boards that displayed information about roadway maintenance schedules.
- 5 (4.2%)—had not seen these messages.

For the tenth and final question on the survey, the participants were again asked to respond by marking a scale which ranged from 1 to 7—on this scale "1" meant "Not at all useful" and "7" meant "Very useful."

The tenth question asked the participants, "How useful to you is information about roadway maintenance schedules?" Figure 4.6 presents the distribution of the ratings given by the 116 participants who responded to this question.

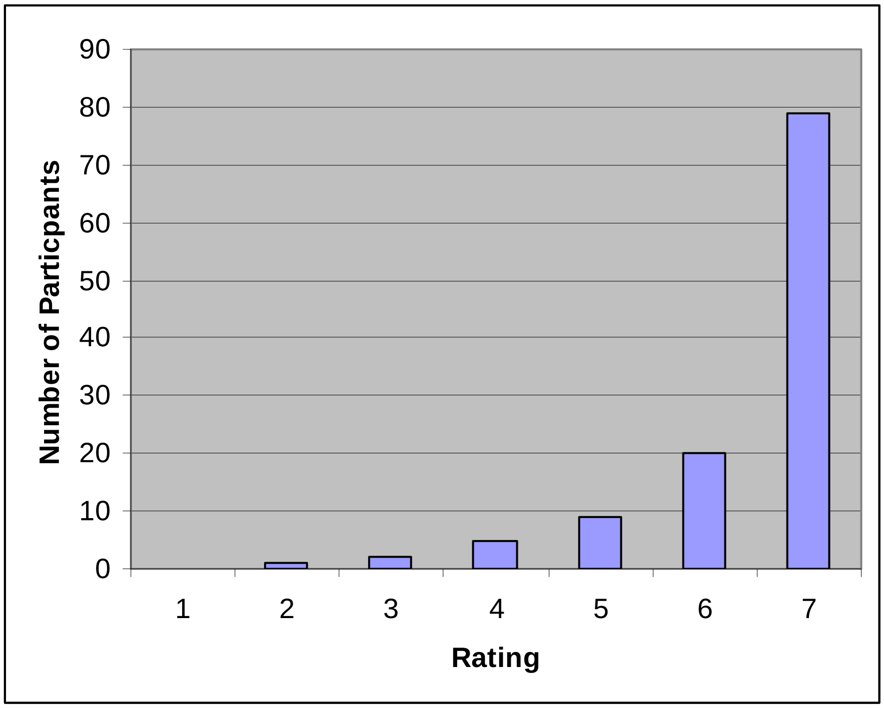

Figure 4.6. Distribution of responses rating the usefulness of information about roadway maintenance schedules.

Inspection of Figure 4.6 shows that the distribution of the participants' ratings of usefulness of information about roadway maintenance schedules was highly positively skewed—79 of the participants (68.1%) gave the highest rating. The mean rating value was 6.42, and the standard deviation was 1.11. These results indicate that there is a very high approval rating for the provision of information about roadway maintenance schedules.

Chapter 5
Traffic Speed and Real-World CMS Messages

5.1 Availability of Data

In order to explore the question of whether CMS messages affect traffic speeds in real world driving, we examined real-world speed data obtained when CMS messages were displayed. The Mn/DOT RTMC has access to data from a number of single loop detectors, as well as from double loop detectors in two locations in the Twin Cities metropolitan area. The single loop detectors provide reliable traffic volume and occupancy data, however they do not provide speed data that are sufficiently reliable for our analysis. As mentioned earlier, Huey and Margulici (2006) attempted to determine whether presenting travel time information on CMS displays resulted in traffic slowing down. It is possible that Huey and Margulici were unable to find reliable evidence of reductions in speed because the unit of measure that they used, average hourly traffic speeds, was not detailed enough. The data from the RTMC double loop detectors are more detailed than the data available to Huey and Margulici. RTMC's double loop detectors provide average traffic speed and traffic volume data every 30 seconds. We believed that the data from these double loop detectors might allow us to detect real-world speed reductions when CMS messages are deployed.

However, there are some problems with using RTMC's double loop detector data to investigate the effects of CMS messages on traffic speed. First, at one location, on MTH-10, the double loop detectors are located approximately 1,200 meters (or 3,937 feet) ahead of the nearest CMS display. This is more than four times further than distance at which drivers are typically able to read CMS messages. It is extremely unlikely that any slow downs that might occur because CMS messages are displayed would propagate back to the location of these double loop detectors. Therefore, the speed data from the double loop detectors located on MTH-10 were not used for comparison purposes.

The other Twin Cities location at which double loop detectors are installed is on I-35W near 73rd Street. In this case, the detectors are located slightly downstream from the nearest CMS display. The RTMC reports that the detectors are located a few hundred feet (between 100 and 300 feet) from this CMS display. It is possible that, if drivers slow down on the approach to this display at a distance from which they can read the CMS message—i.e., when they are between 860 feet (262.1 meters) and 0 feet (0 meters) from the display—then they may still be driving slower a few hundred feet after they have passed beneath the CMS display.

There is an additional problem with the double loop detectors on I-35W near 73rd Street. This problem is that the detectors have not been calibrated for five years. Because of this, we cannot rely on them to provide accurate *absolute* speed data. However, they should provide reliable *comparative* speed data—if we find differences in speed, then the differences should be reliable.

Because of the problems with the double loop detectors installed on I-35W near 73rd Street—that they are located downstream from the nearest CMS display and have not been calibrated for five years—it is not meaningful to use data from them to make direct comparisons with the data we obtained in the simulator experiments. However, these data can be examined to discover whether they are consistent with the possibility that the deployment of CMS messages may affect traffic speeds. We examined data obtained from these double loop detectors at the time that six incidents occurred in March and April of 2008. For one of the six incidents, two different CMS messages were deployed—first, drivers were advised to use caution and then they were informed that a ramp had been closed. For the other five incidents, a single CMS message was deployed. Our analysis of the data obtained from the double loop detectors installed on I-35W near 73rd Street when these six incidents occurred, is presented below.

5.2 Analysis of Real-World Data

For each incident, we obtained data from double loop detectors installed in the Southbound Middle Lane and Right Lane on I-35W near 73rd Street. The data were in the form of average speed data and traffic volume data—these data were collected every 30 seconds.

For each incident, approximately 60 minutes of data were available. For all six incidents, data were obtained from the period *immediately* before the CMS messages were deployed, and from the period *during* which the message was deployed. In addition in some cases, data were also available from the period immediately following the removal of the message.

For five of the incidents, we were able to compare the test data with data obtained exactly one week later, during the same time periods in which the test data were collected. For the other incident, there was a problem with the radio link to one of the detectors one week later during the time in which the test data were collected. As a result, the comparison data for that incident were obtained two weeks after the test day. [Also for one incident, fewer minutes of data were available for the Middle Lane than the Right Lane, because of two very brief radio link failures (of one and three minutes).]

Our objective was to examine the data from the test and comparison days in order to determine whether traffic speeds were slower when CMS messages were deployed. If any differences in the traffic speeds on the test day and the comparison day could be considered as evidence supporting the possibility that traffic speeds are slower when CMS messages are deployed, then it would be necessary for the traffic conditions to be similar on the test day and the comparison day. Specifically, the following criteria would need to be met:

- Traffic volumes should be similar (or at least, not statistically significantly different) in the pre-deployment period on both the test day and the comparison day.
- Traffic volumes should be similar (or at least, not statistically significantly different) during the deployment period on both the test day and the comparison day.
- Traffic speeds should be similar (or at least, not statistically significantly different) in the pre-deployment period on the test day and the comparison day.
- And finally, traffic speeds should be similar in the pre-deployment period and the deployment period on the comparison day.

If these criteria are not met, then differences in speed during the deployment period on the test day and the comparison day should not considered evidence that supports the notion that traffic speeds are slower when CMS messages were deployed.

In order to compare the test data and the comparison data we conducted a series of *t*-tests. We compared the speed data and traffic volume data obtained in the period of time before the CMS messages were deployed on each test day with the equivalent data from the comparison day. After comparing the pre-deployment data, we conducted a second series of *t*-tests, this time comparing the speed and volume data obtained during the time the CMS message was deployed on each test day with the equivalent speed and volume data obtained on the comparison day. And then, after comparing the deployment data, if possible we conducted a third series of *t*-tests in which we compared the post-deployment speed and volume data obtained on the test day with the data from the same time period on the comparison day.

5.3 Results

The results of the statistical analyses of the six incidents that occurred in March and April of 2008 are described in the sub-sections below.

5.3.1 "Abducted Child" Message

The first of the six incidents involved an abducted child. A CMS message providing information about this incident was deployed on Friday March 7, 2008, between 5:00 p.m. and 7:05 p.m. We obtained comparison data from the same time of day one week later, on Friday March 14, 2008. The text of the CMS message was as follows:

ABDUCTED CHILD GRN CHRYSLER CONV MN LIC # RM086

For this incident, ten minutes of pre-deployment data and 59.5 minutes of deployment data were available—but there were no post-deployment data. The average traffic volumes on the test day and on the comparison day in the pre-deployment and deployment time periods for the double loop detectors in the middle and right lanes were compared using *t*–tests. Table 5.1 presents the average volumes for the test day and the comparison day. The table also indicates which differences between the average volumes for the test day and the comparison day were statistically significant—for the differences that were statistically significant the *p*–value is entered in the table and the *lower volume* is bolded. For the differences that were not significantly different "*ns*" is entered in the table.

Table 5.1. Average traffic volumes on the test (Test) and the comparison (Comp) days in the pre-deployment and deployment time periods in the middle lane and right lane for the "Abducted Child" message.

Period	**Pre-Deployment**			**During Deployment**		
Length of Period	10 minutes			59.5 minutes		
Day	Test	Comp	*p*	Test	Comp	*p*
Middle Lane	12.75	13.45	*ns*	**11.70**	12.75	0.0133
Right Lane	13.55	12.25	*ns*	**11.61**	12.41	0.0314

Table 5.1 shows that in the pre-deployment period, the traffic volumes were not statistically significantly different on the test day and the comparison day. However, the table does show that during the deployment period, there were significant differences: In both the middle and right lanes there were significantly lower vehicle volumes on the test day than there were on the comparison day—unfortunately this violates the criterion that "Traffic volumes should be similar (or at least, not statistically significantly different) during the deployment period on both the test day and the comparison day."

We also compared the average speeds on the test day and on the comparison day in the pre-deployment and deployment time periods in the middle and right lanes. Table 5.2 presents the average speeds for the test and comparison days. The table also indicates statistically significant differences between the speeds for the test day and the comparison day by presenting the *p*–value in the table and bolding the s*lower speed*—"*ns*" is entered when the differences were not statistically significant.

Table 5.2. Average speed on the test (Test) and the comparison (Comp) days in the pre-deployment and deployment time periods in the middle lane and right lane for the "Abducted Child" message.

Period	**Pre-Deployment**			**During Deployment**		
Length of Period	10 minutes			59.5 minutes		
Day	Test	Comp	*p*	Test	Comp	*p*
Middle Lane	48.45	**47.20**	**0.0136**	47.11	45.86	*ns*
Right Lane	47.50	**46.15**	**0.0387**	45.87	46.08	*ns*

Table 5.2 shows that in the pre-deployment period, the traffic speeds were significantly different on the test day in both the middle lane and right lane, with the vehicles traveling slower on the comparison day than the vehicles on the test day. This result violates the criterion that, "Traffic speeds should be similar (or at least, not statistically significantly different) in the pre-deployment period on the test day and the comparison day."

With one criterion related to traffic volume and another related to traffic speed violated, it is not meaningful to comment on whether the "Abducted Child" message deployed on Friday March 7, 2008 might have affected traffic speeds.

5.3.2 "Incident on Ramp" Message

The second incident for which we obtained data involved a crash on a ramp. The CMS message in this case was deployed on Wednesday March 22, 2008, between 5:56 a.m. and 6:05 a.m. The comparison day data were obtained at the same time of day, one week later, on Wednesday March 19. The text of this message for this incident was as follows:

INCIDENT ON RAMP TO 494 WEST USE CAUTION

In this case, for the right lane, there were 10.5 minutes of pre-deployment data, 8.0 minutes of deployment data, and 25.5 minutes of post-deployment data available for analysis. However, because of two very brief failures of the radio link to the middle lane detector on the test day, there were fewer minutes of data available for the middle lane—there were 9.5 consecutive minutes for the pre-deployment period and 22.5 consecutive minutes for post-deployment period. Table 5.3 presents the average volumes for the test day and the comparison day, and shows the results of the comparisons made using *t*-tests—in this case, there were no statistically significant differences.

Table 5.3. Average traffic volumes on the test (Test) and the comparison (Comp) days in the pre-deployment, deployment, and post-deployment time periods in the middle lane and right lane for the "Incident on Ramp" message.

Period	**Pre-Deployment**			**During Deployment**			**Pos-Deployment**		
Length of Period	9.5 minutes (for Middle lane) 10.5 minutes (for Right Lane)			8 minutes			22.5 minutes (for Middle lane) 25.5 minutes (for Right Lane)		
Day	Test	Comp	*p*	Test	Comp	*p*	Test	Comp	*p*
Middle Lane	4.63	5.11	*ns*	4.94	4.47	*ns*	5.41	5.09	*ns*
Right Lane	5.23	5.00	*ns*	4.88	4.94	*ns*	6.53	6.02	*ns*

Table 5.3 shows that there were no statistically significant differences in the traffic volumes on the test day and the comparison day in the pre-deployment, deployment, and post-deployment time periods. Therefore for this incident, the traffic volume data were in accordance with the criteria necessary for making meaningful comparisons of the speed data.

The results of comparing the average speeds on the test day with the speeds on the comparison day in the pre-deployment, deployment, and post-deployment time periods are shown in Table 5.4. Where there was a statistically significant difference, the *p*–value is entered and the s*lower speed* is bolded in the table—and where the differences were not statistically significant, "*ns*" is entered in the table.

Table 5.4. Average speed on the test (Test) and the comparison (Comp) days in the pre-deployment, deployment, and post-deployment time periods in the middle lane and right lane for the "Incident on Ramp" message.

Period	**Pre-Deployment**			**During Deployment**			**Post-Deployment**		
Length of Period	9.5 minutes (for Middle lane) 10.5 minutes (for Right Lane)			8 minutes			22.5 minutes (for Middle lane) 25.5 minutes (for Right Lane)		
Day	Test	Comp	*p*	Test	Comp	*p*	Test	Comp	*p*
Middle Lane	48.63	48.42	*ns*	**47.44**	50.38	0.0003	48.80	49.13	*ns*
Right Lane	48.62	48.05	*ns*	47.81	48.88	*ns*	48.12	48.25	*ns*

Table 5.4 shows that, in the middle lane, during the deployment period the average traffic speed was significantly slower on the test day than it was on the comparison day. Looking at this significant difference in more detail, reveals that on the test day, the average speed dropped by 1.19 mph between the pre-deployment time period (when it was 48.63 mph) and the deployment

period (when it was 47.44 mph). However on the comparison day, the speed *increased* by 1.96 mph between the pre-deployment period (when it was 48.42 mph) and the pre-deployment period (when it was 50.38 mph) in the deployment period)—this increase contributed 65% of the difference in speed between the pre-deployment and deployment periods. And this substantial increase in speed on the comparison day violates the criterion that, "traffic speeds should be similar in the Pre-deployment period and the deployment period on the comparison day." Therefore, it is not meaningful to comment on whether or not the CMS message, providing information about the Incident on the Ramp, that was deployed on Wednesday March 22, 2008, might have affected traffic speeds.

5.3.3 "Crash on the Right Shoulder" Message

The third of the six incidents involved a crash on the right shoulder of I-35W. The crash occurred on Saturday April 12, 2008, and the CMS message giving details of the crash was deployed between 5:28 p.m. and 6:02 p.m. The comparison data were obtained at the same time of day as the incident, one week later—on Saturday April 19, 2008. The text of the CMS message associated with this incident was as follows:

CRASH 494 EAST AT 12TH STREET ON RIGHT SHOULDER

The data that were available for this incident were as follows: 17.5 minutes of pre-deployment data, 34.5 minutes of deployment data, and 7.5 minutes of post-deployment data. The average traffic volumes for the test and comparison days are presented in Table 5.5. The table also shows the results of the comparisons made using *t*-tests—for those differences that were statistically significant the *p*–value is entered in the table and the *lower traffic volume* is bolded. When the differences were not significant, "*ns*" is entered in the table.

Table 5.5. Average traffic volumes on the test (Test) and the comparison (Comp) days in the pre-deployment, deployment, and post-deployment time periods in the middle lane and right lane for the "Crash on the Right Shoulder" message.

Period	**Pre-Deployment**			**During Deployment**			**Post-Deployment**		
Length of Period	17.5 minutes			34.5 minutes			7.5 minutes		
Day	Test	Comp	*p*	Test	Comp	*p*	Test	Comp	*p*
Middle Lane	9.03	9.60	*ns*	**8.74**	10.19	0.0019	**7.60**	10.47	0.0024
Right Lane	13.17	12.29	*ns*	10.78	11.65	*ns*	11.27	12.13	*ns*

Table 5.5 shows that while there were no significant differences in the traffic volumes for the right lane in any of the three time periods, there were significant differences in traffic volume in

the middle lane in the deployment and post-deployment time periods. Thus, the criterion that, "Traffic volumes should be similar (or at least, not statistically significantly different) during the deployment period on both the test day and the comparison day" was violated, as far as the middle lane was concerned.

The average traffic speeds for the test and comparison days are given in Table 5.6 below. The table also presents the results of the *t*-tests comparing the average speeds on the test day and the comparison day in the pre-deployment, deployment, and post-deployment time periods. When the differences were significant, the *p*–value is entered in the table—and the s*lower speed* is bolded. When the differences were not significant, "*ns*" is entered in the table.

Table 5.6. Average speed on the test (Test) and the comparison (Comp) days in the pre-deployment, deployment, and post-deployment time periods in the middle lane and right lane for the "Crash on the Right Shoulder" message.

Period	**Pre-Deployment**			**During Deployment**			**Post-Deployment**		
Length of Period	17.5 minutes			34.5 minutes			7.5 minutes		
Day	Test	Comp	*p*	Test	Comp	*p*	Test	Comp	*p*
Middle Lane	49.40	49.83	*ns*	49.20	49.32	*ns*	51.33	**48.60**	0.0002
Right Lane	47.82	48.40	*ns*	47.71	48.20	*ns*	49.47	**47.40**	0.0004

Table 5.6 shows that, during the pre-deployment and deployment periods, the mean speeds were not significantly different on the test and comparison day in either lane. Interestingly, in the post-deployment period, there were significant increases in speed on the test day.

As with the first two incidents, the analysis indicated that it is not meaningful to comment on whether or not the CMS message that gave details of the crash on the right shoulder of I-35W on Saturday April 12, 2008 might have affected traffic speeds.

5.3.4. "Grass Fire" Message

The fourth incident was a grass fire that resulted in the closure of the right lane on Southbound I-35W on Tuesday April 15, 2008. The CMS message giving information about the grass fire was deployed between 10:10 a.m. and 10:48 a.m. The comparison data for this incident were obtained from the same time of day *two* weeks later, on Tuesday April 29, 2008—this was because there was a problem with the radio link to double-loop detector in the middle lane on what would otherwise have been the comparison day. The text of the CMS message that was deployed for this incident was as follows:

GRASS FIRE SOUTH OF MN RIVER RIGHT LANE CLOSED

For the grass fire incident, data were available for 19.5 minutes in the pre-deployment period and 38.5 minutes in the deployment period. However, no post-deployment data were available. Table 5.7 shows the average traffic volumes in the pre-deployment and deployment period for the test and comparison days. The table also presents the results of the *t*-tests comparing the traffic volumes on the test day and the comparison day. There was one difference that was significant—the *p*–value for this difference is entered in the table—and the *lower traffic volume* is bolded.

Table 5.7. Average traffic volumes on the test (Test) and the comparison (Comp) days in the pre-deployment and deployment time periods in the middle lane and right lane for the "Grass Fire/Right Lane Closed" message.

	Pre-Deployment			**During Deployment**		
Length of Period	19.5 minutes			38.5 minutes		
Day	Test	Comp	*p*	Test	Comp	*p*
Middle Lane	7.79	7.33	*ns*	7.79	7.40	*ns*
Right Lane	10.62	9.74	*ns*	11.05	**9.10**	0.0005

Table 5.7 shows that there were no significant differences in the traffic volumes for the middle lane in either the pre-deployment or deployment time periods. However, there was a significant difference in the right lane in the deployment time period. The criterion that, "Traffic volumes should be similar (or at least, not statistically significantly different) during the deployment period on both the test day and the comparison day" was violated, at least for the right lane on the test day.

Table 5.8 presents the average traffic speeds for the test and comparison days. In addition, the table also gives the results of the *t*-tests comparing average speeds on the test and comparison days in the pre-deployment and deployment time periods. In this case all four comparisons involved statistically significant differences—the *p*–values are entered in the table, and the s*lower speeds* are bolded.

Table 5.8. Average speed on the test (Test) and the comparison (Comp) days in the pre-deployment, deployment, and post-deployment time periods in the middle lane and right lane for the “Grass Fire/Right Lane Closed” message.

Period	**Pre-Deployment**			**During Deployment**		
Length of Period	19.5 minutes			38.5 minutes		
Day	Test	Comp	*p*	Test	Comp	*p*
Middle Lane	**45.51**	47.67	<0.0001	**45.22**	47.45	<0.0001
Right Lane	**45.28**	46.46	0.0144	**43.58**	46.01	<0.0001

Table 5.8 shows that, in both the pre-deployment and deployment time periods, the mean speeds were significantly slower on the test day than they were on the comparison day in the middle and right lanes. The fact that traffic speeds were not similar in the pre-deployment period on the test and comparison days violates one of our criteria. Again, it is not meaningful to comment on whether or not the CMS message that gave details of the grass fire might have affected traffic speeds.

5.3.5 “Incident on Ramp” and “Exit Ramp Closed” Messages

The fifth incident, which involved a crash on the ramp at 90th Street, resulted in two consecutive CMS messages. The incident occurred on Wednesday April 16, 2008. Comparison data were obtained one week later on Wednesday April 23, 2008. The first of the two messages, which was deployed at 11:04 a.m., read as follows:

INCIDENT ON RAMP AT 90TH ST USE CAUTION

This message was replaced at 11:16 a.m. by the following CMS message (which was removed at 12:13 p.m.):

EXIT RAMP CLOSED AT 90TH ST USE OTHER ROUTES

For this incident, there were 19 minutes of pre-deployment data. Then, there were 11 minutes of data obtained during the deployment of the first message, followed by a further 29 minutes of data obtained during the deployment of the second message. Table 5.9 shows the average traffic volumes during these three periods for the test and comparison days. The table also presents the results of the *t*-tests comparing traffic volumes on the test and comparison days in the three periods. For this incident, there were no statistically significant differences in traffic volumes—consequently, "*ns*" is entered in the table.

Table 5.9. Average traffic volumes on the test (Test) and the comparison (Comp) days in the pre-deployment period and the deployment period in the middle lane and right lane for the first ("Incident on Ramp") and second ("Exit Ramp Closed") messages.

Period	**Pre-Deployment**			**During Deployment of First Message**			**During Deployment of Second Message**		
Length of Period	19 minutes			11 minutes			29 minutes		
Day	Test	Comp	*p*	Test	Comp	*p*	Test	Comp	*p*
Middle Lane	8.16	8.00	*ns*	8.68	7.95	*ns*	8.90	9.17	*ns*
Right Lane	10.97	10.74	*ns*	10.59	11.23	*ns*	11.05	11.67	*ns*

As Table 5.9 shows there were no significant differences in traffic volumes during the pre-deployment period or during the deployment periods for the first and second CMS messages associated with this incident. Therefore, there were no violations of the criteria that need to be satisfied in order that meaningful comparisons can be made.

The average traffic speeds for the pre-deployment period and the deployment periods for the first and second messages are shown in Table 5.10. The speeds are shown along with the results of the *t*-tests comparing the average speeds on the test and comparison days. For statistically significant speed differences, the *p*–value is entered in the table—and the s*lower speed* is bolded. When the differences were not significant, "*ns*" is entered in the table.

Table 5.10. Average speed on the test (Test) and the comparison (Comp) days in the pre-deployment period and the deployment period in the middle lane and right lane for the first ("Incident on Ramp") and second ("Exit Ramp Closed") messages.

Period	**Pre-Deployment**			**During Deployment of First Message**			**During Deployment of Second Message**		
Length of Period	19 minutes			11 minutes			29 minutes		
Day	Test	Comp	*p*	Test	Comp	*p*	Test	Comp	*p*
Middle Lane	47.87	48.26	*ns*	**46.64**	47.86	0.0190	**47.38**	48.17	0.0092
Right Lane	46.97	47.39	*ns*	45.77	46.59	*ns*	45.88	46.28	*ns*

Table 5.10 shows that for the right lane, the mean speeds were not significantly different in any of the three periods. The table also shows that, for the middle lane, the mean speeds were not

different in the pre-deployment period. However, during the deployment period for both the first and second messages, the traffic speeds *were* statistically significantly slower on the test day than they were on the comparison day.

The statistically significant differences in traffic speed between the test Day and the comparison Day that occurred in the middle lane during the deployment periods for the first and second message are illustrated in Figure 5.1, below

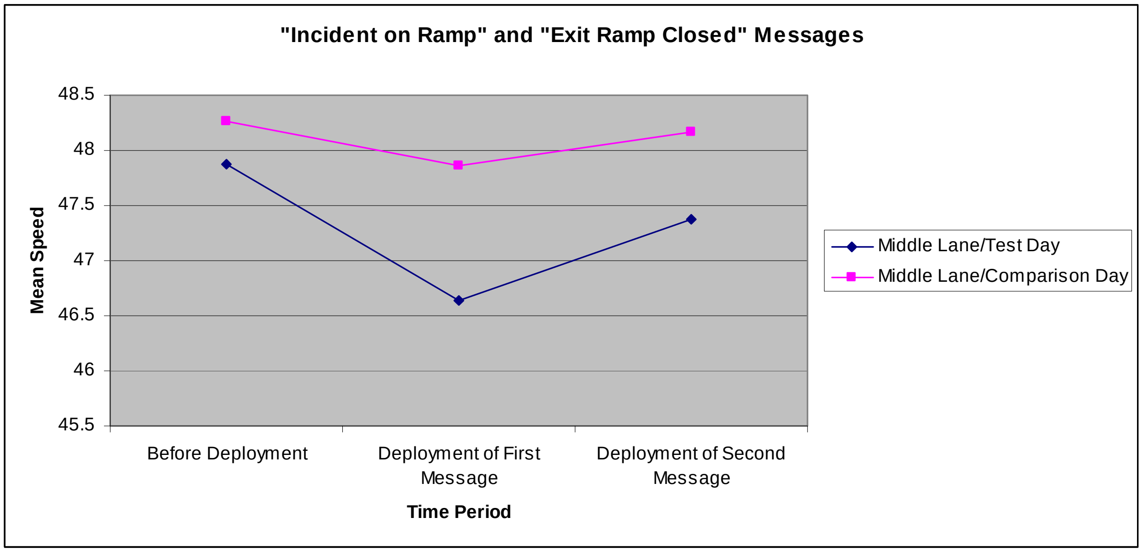

Figure 5.1. Mean speeds on the test and comparison days in the middle lane of Southbound I-35W near 73rd Street, during the pre-deployment and deployment periods for the "Incident on Ramp" and "Exit Ramp Closed" messages.

For the fifth of the six incidents, the criteria that we suggested were necessary for the comparisons to meaningful were in fact met. And, as Table 5.10 indicates and Figure 5.1 illustrates, during deployment of both the first message ("Incident on Ramp") and second message ("Exit Ramp Closed") the traffic speeds for the middle lane *were* statistically significantly slower on the test day than they were on the comparison day. This result is consistent with the suggestion that deployment of CMS messages may lead to slower driving speeds in real-world driving.

5.3.6 Second "Crash on Shoulder" Message

The sixth and final incident for which we obtained speed and volume data involved a second crash on the shoulder of I-35W. For this incident, a CMS message was deployed on Friday March 18, 2008, between 7:41 a.m. and 8:22 a.m. Comparison data were obtained at the same time of day one week later, on Wednesday March 19, 2008. The text of this CMS message for this incident was as follows:

CRASH 494 WEST AT PENN AV ON RIGHT SHOULDER

For this incident, we were able to analyze 11 minutes of data from the pre-deployment period, 40.5 minutes of data from the deployment period, and 7.5 minutes of data from the post-deployment period. Table 5.11 presents the average traffic volumes during these three periods for the test and comparison days. The table also presents the results of the *t*-tests comparing traffic volumes on the test and comparison days in the three periods. For the differences that were significant, the *p*–value is entered in the table—and the *lower traffic volume* is bolded.

Table 5.11. Average traffic volumes on the test (Test) and the comparison (Comp) days in the pre-deployment and deployment time periods in the middle lane and right lane for the second "Crash on Right Shoulder" message.

Period	**Pre-Deployment**			**During Deployment**			**Post-Deployment**		
Length of Period	11 minutes			40.5 minutes			7.5 minutes		
Day	Test	Comp	*p*	Test	Comp	*p*	Test	Comp	*p*
Middle Lane	14.82	**12.05**	0.0010	15.14	**13.81**	0.0082	13.33	13.67	*ns*
Right Lane	16.95	**14.73**	0.0108	18.69	18.53	*ns*	17.07	17.33	*ns*

Table 5.11 indicates that in both the middle and right lanes in the pre-deployment period, the traffic volumes were significantly different on the test and comparison days—with lower volumes on the comparison day in both lanes. The table also shows that during the deployment period, there was a significant difference in the middle lane—there was a lower vehicle volume on the comparison day than there was on the test day. The difference was not statistically significant during the deployment period in the right lane; and the differences were not statistically significant during the post-deployment period in either lane. These results violate the criteria that (1) "Traffic volumes should be similar (or at least, not statistically significantly different) during the pre-deployment period on both the test day and the comparison day," and (2) "Traffic volumes should be similar (or at least, not statistically significantly different) during the deployment period on both the test day and the comparison day"—(they were not similar in the middle lane).

The average traffic speeds for the pre-deployment, deployment, and post-deployment periods for the first and second Messages are shown in Table 5.12. The speeds are shown along with the results of the *t*-tests comparing the average speeds on the test and comparison days. When the differences were statistically significant, the *p*–value is entered in the table, and the s*lower speed* is bolded. When the differences were not significantly different, "*ns*" is entered in the table.

Table 5.12. Average speed on the test (Test) and the comparison (Comp) days in the pre-deployment and deployment time periods in the middle lane and right lane for the second "Crash on Right Shoulder" message.

Period	**Pre-Deployment**			**During Deployment**			**Post-Deployment**		
Length of Period	11 minutes			40.5 minutes			7.5 minutes		
Day	Test	Comp	*p*	Test	Comp	*p*	Test	Comp	*p*
Middle Lane	47.00	46.18	*ns*	**43.56**	45.30	0.0001	47.67	46.53	*ns*
Right Lane	45.14	44.55	*ns*	**39.68**	42.21	<0.0001	45.33	**43.33**	0.0332

Table 5.12 indicates that while speeds were similar on the test and comparison days in the pre-deployment period, there were significant slow downs on the test day during the deployment period. This particular result would provide quite compelling evidence that CMS messages can cause slow downs in real-world traffic—except that our criteria with regard to volume were violated, and all we can say is that for this incident it is not meaningful to comment on whether or not the CMS message associated with it affected traffic speeds.

5.4 Summary

To explore the question of whether CMS messages affect traffic speeds in real world driving, we examined real-world speed data obtained by RTMC when CMS messages were deployed. The data came from double loop detectors in the middle and right lanes of Southbound I-35W near 73rd Street that are located a few hundred feet (between 100 and 300 feet) downstream from the nearest CMS display. It is possible that if drivers slow down on the approach to this CMS display, then they may still be driving slower a few hundred feet after they have passed beneath it. These double loop detectors cannot be relied on to provide accurate *absolute* speed data, because they have not been calibrated for five years. However, they should provide reliable *comparative* speed data. Because of the problems with the double loop detectors, it is not meaningful to use data from them to make direct comparisons with the data obtained in the simulator experiments. However, we were able to analyze the data obtained from them to determine whether traffic speeds were consistent with traffic slow downs that could be caused by the deployment of CMS.

We analyzed data obtained at the time that CMS messages were deployed in connection with six incidents that occurred in March and April of 2008. We compared data obtained on the day that each incident occurred with comparison data obtained at the same time of day one week later. In order for comparisons to be meaningful, several criteria needed to be met: that (1) traffic volumes should be similar in the pre-deployment period on both the test day and the comparison day; (2) traffic volumes should be similar during the deployment period on both the test day and the comparison day; (3) traffic speeds should be similar in the pre-deployment period on the test day and the comparison day; and (4) traffic speeds should be similar in the pre-deployment period and the deployment period on the comparison day.

For five of the incidents at least one of these criteria was violated. The remaining incident involved a crash on the ramp at 90th Street that occurred on Wednesday April 16, 2008. For this incident two consecutive CMS messages were deployed. Our analysis showed that during deployment of both the first message (which was “Incident on Ramp/At 90th St/Use Caution”) and the second message (“Exit Ramp Closed/At 90th St/Use Other Routes”) the traffic speeds for the middle lane *were* statistically significantly slower on the test day than they were on the comparison day (the differences were not significant for the right lane). This result is consistent with the suggestion that the deployment CMS messages can lead to slower driving speeds in real-world driving.

Chapter 6
Observations of RTMC Operations

6.1 Introduction

As part of the Phase II investigation into the effectiveness and safety of traffic and non-traffic related messages presented on CMSs, we visited Mn/DOT's Regional Transportation Management Center (RTMC) several times to observe work processes in the Operations Center. During our visits, we focused on traffic operations and the decision-making processes that are involved in deploying traffic-related CMS messages.

We observed operations at the RTMC during both morning and afternoon peak traffic periods. We also conducted interviews with RTMC personnel to gain a better understanding of the process regarding deployment of CMSs

It should be noted that there were two types of CMS message that we did not consider during our observations and interviews. First, we did not consider the processes involved when time-critical, non-site specific "Abducted Child" messages are deployed. This is because Operation Center operators do not carry out the decision-making processes involved when these messages are deployed. Rather, Mn/DOT deploys "Abducted Child" messages at the request of the Minnesota Department of Public Safety; these messages are deployed in cases of child abduction, when a child is in danger, and when descriptive information about the child, the suspect and/or the getaway car is available.

Second, we did not consider the processes involved when non-time critical, non-site specific, messages, such as "Stay with Your Vehicle When Stalled" or "Extra Troopers Working this Weekend," are deployed. Decisions to deploy non-time critical, non-site specific, messages are not made in real time by the operators in response to current traffic conditions. These messages are deployed at preplanned times, and often coincide with other Mn/DOT initiatives.

During our observations and interviews, we focused on the decision-making processes used by RTMC operators when they decide to deploy, change, and remove CMS messages that provide information about incidents to the driving public.

6.2 The RTMC Operations Center

In the RTMC Operations Center, personnel from Mn/DOT Operations Management, Mn/DOT Maintenance Dispatch, and State Patrol Dispatch work together. Their operating stations are arranged at strategic points facing a wall containing several banks of monitors. The monitors show imagery as it is obtained, in real time, by surveillance cameras that are positioned close to roadways in the Twin Cities metropolitan area. The RTMC has approximately 430 surveillance cameras. These cameras provide coverage of approximately 400 miles of roadways in the Twin Cities.

In each bank of monitors, the top two rows are reserved for camera views of current incidents. Views from the other surveillance cameras are presented in cyclical fashion on the lower two rows of monitors. Between the banks of monitors there are maps showing the freeway network in the Twin Cities metropolitan area. The maps indicate (1) the locations of current incidents, (2) the locations of the surveillance cameras, (3) current congestion levels, and (4) the locations of work zones.

At each operating station, there are four flat-panel monitors on which the Operations Center personnel, both dispatchers and operators, can display views from any of the surveillance cameras. The operators and dispatchers can control each camera individually. The dispatchers and operators also use the monitors on their desks to display traffic maps and a log of current incidents.

6.3 Detecting Incidents

We learned that the Operations Center personnel obtain information about incidents from several sources. Much of the incident information is provided by State Patrol officers and by members of the Freeway Incident Response Safety Team (FIRST—previously known as Highway Helpers), who continually driving the freeways. Incident information is also provided directly to the Operations Center by members of the public. If an incident involves a stalled vehicle, a crash, or debris on the roadway, FIRST units and/or State Patrol officers respond to that incident.

Dispatch personnel give information about incidents to traffic operations personnel. When a traffic operations operator receives information about a specific incident, he or she locates the nearest surveillance camera to the incident. Then, by panning and zooming with that camera, the operator finds the best available view of the vehicle that has stalled, the vehicle or vehicles that have crashed, or of the debris. In our interviews with RTMC personnel, we were told that occasionally they receive a report of an incident that they cannot be located with a surveillance camera—because the line of sight between the nearest camera and the incident is obscured. Apparently, this occurs relatively infrequently, which is fortunate because, as we were told, the ability to verify an incident is very important—the operator needs to have a direct camera view of each incident, so that he or she can monitor the status of the incident and manage the CMS messages associated with it. When the operator finds the best view from one of the surveillance cameras, he or she displays that view in the top two rows of the bank of monitors.

6.4 Managing Incidents

Depending on the specific details of each incident, the operator decides whether or not to deploy a message on a CMS display (or displays) upstream from the incident, in order to provide a warning of potential hazard to oncoming drivers. In some cases, the operator may also deploy messages on CMS displays located on roads feeding into the roadway on which the incident has occurred. We learned that the operator makes the decision whether or not to deploy a CMS message, or messages, and decides what text should be used in the message(s) based on the following factors:

- The severity of the particular incident.
- The specific location of the incident on the road network.
- Where the incident has occurred relative to the roadway (i.e., whether it affects one or more lanes, or is on the shoulder to the right or left).
- Current traffic conditions.
- How the incident is likely to affect traffic flow.
- And on the knowledge and experience of the operator.

Typical ways in which CMS messages can be deployed are detailed below.

- If the incident—the vehicle, vehicles, or the debris—affects all the driving lanes, then CMS messages will be deployed at several CMS locations upstream from the location of the incident, informing drivers that there are likely to be major delays and that they should seek alternate routes. Also in this case, messages are likely to be deployed, where possible, on CMS displays located on feeder road.
- If the incident affects one or more lanes—but not all lanes—then the operator will deploy a message on the nearest CMS displays upstream and, possibly, on additional CMS displays still further upstream from the incident and on feeder roads.
- If the incident occurs on the left shoulder, the operator will probably deploy a CMS message, particularly if a stalled vehicle, vehicles involved in a crash, or debris is close to the left lane, and/or if the road curves, or there is an overpass upstream from the site of the incident that may obscure the view of an oncoming driver.
- If the incident is on the right shoulder, the operator is less likely to deploy a CMS message than if it is on the left shoulder—although, again, a message will be deployed if a stalled vehicle, vehicle(s) involved in a crash, or debris is close to the right lane and/or if there is a curve or an overpass upstream from the incident site which may obscure the view of an oncoming driver.
- If the incident occurs on an entry or exit ramp and blocks the ramp, then it may be necessary for the operator to close the ramp, sometimes for an extended period of time—as happened while we were observing, when an oil tanker overturned on the exit ramp on I-35W at County Road C. In this case, the ramp was closed for at least eight hours, and CMS messages were deployed at a number of sites on I-35W, as well as on several feeder roads, informing drivers of the ramp closure.
- If the incident occurs on an entry or exit ramp and affects a lane but does not completely block the ramp, then CMS messages may be deployed at several CMS locations, informing drivers that there may be traffic delays and/or that they should seek alternate routes.
- If the incident occurs on an entrance or exit ramp but is confined to the right or left shoulder, it may not be necessary to deploy a CMS message.
- If the incident occurs on an overpass and there is the potential for disruption on the roadway below, it may be necessary to deploy CMS messages upstream to warn oncoming traffic on the roadway below. We observed an incident of this kind when the load on a semi-trailer truck came loose and the truck stopped on Yankee Doodle Boulevard on the overpass above I-35E. There was a possibility that part of the load could be dislodged and might fall from the tuck and off the overpass onto the freeway

below. CMS messages warning of this hazard were deployed upstream from the overpass—and, eventually, a State Patrol vehicle was used to block the lane upstream from the potential hazard.

The operator monitors each new incident, whether or not he or she deploys a CMS message, and continues to monitor other incidents that occurred earlier. The operator pays particular attention to the changing status of each incident. For example, when a State Patrol officer and/or a FIRST responder arrives on the scene, the status of the incident often changes—more lanes may be blocked, or an incident that was initially confined to the right or left shoulder may now encroach into the traffic lanes. Then, the operator may need to change the text of an already-deployed CMS message, in order to indicate both changes in the specifics of the incident and possible changes in how the incident may affect oncoming traffic. The operator continues to monitor incidents as they evolve, making adjustments to the text of the CMS messages as necessary.

The operator also keeps track of the whereabouts of the occupant(s) of vehicles that have stalled or are involved in a crash. Sometimes occupants exit their vehicle(s), and may leave the scene—then FIRST units and/or State Patrol officers need to be informed, as the actions of occupant(s) affect how the incident will be resolved.

In addition, the operator keeps a log of each incident. This log details which camera is used to monitor the incident, provides a brief description of the incident (e.g., “Fire, Vehicle,” “Stall,” “Crash,” “Unoccupied Stall,” etc), indicates the location of the incident (e.g., T.H. 169 at Medicine Lk Rd), and whether or not traffic is blocked, and gives the date and start time of the incident.

In managing an incident, the operator uses the surveillance camera nearest the location of the incident, as well as cameras located upstream from the incident, in order to determine whether there are increases in traffic density and corresponding reductions in the speed of the oncoming traffic. If there are reductions in speed upstream and traffic congestion occurs as the result of an incident, then the operator may decide to deploy additional CMS messages still further upstream, or on feeder roads, warning drivers that delays may be likely and/or that they should consider alternative routes. Decisions whether or not to deploy additional CMS messages will depend upon how much of a ripple effect the incident is likely to have, and on the distance from the incident to the additional CMS sites. In peak traffic periods, ripple effects are much more likely to occur and traffic delays are likely to propagate at faster rates. Decisions about whether or not to deploy additional CMS messages further upstream are made by the operator, based on current traffic conditions and his or her knowledge and experience. [It has been suggested that computational aides or algorithms might be developed in order to help operators make decisions about the deployment of additional CMS messages as traffic densities increase and traffic speeds slow upstream from specific incidents. The difficulty of developing such computational aides or algorithms is discussed below in the final subsection of this chapter.]

We learned that when incidents are finally cleared, the operator may simply remove the CMS message(s) associated with the incident or may change the CMS messages before finally removing them. If the incident had a minimal affect on traffic flow, the operator is more likely to simply remove the CMS message(s) associated with the incident. However, some incidents have prolonged effects on traffic flow, leading to considerable reductions in speed, and producing congestion upstream that may take some time to dissipate. When incidents that have these effects are cleared, then the operator will deploy CMS messages that inform oncoming drivers that the incident (typically a crash) has been cleared, but warning them that they might still encounter congestion. We were told that RTMC deploys this type of message in order to keep drivers informed and explain how current traffic conditions have occurred. The operators remove this type of CMS message when the congestion finally dissipates—they might be deployed for up to five minutes after the incident has cleared.

On the days that we visited the RTMC, there were relatively incidents. We observed that the operators were able to respond to the incidents rapidly and manage them very efficiently. We learned that sometimes in peak periods, particularly when there is snow, there are more incidents and that, consequently, it is considerably more difficult to manage them. However, we believe that the decision-making processes that the RTMC Operations Center personnel currently have in place are sound and very efficient.

6.5 The Difficulty of Developing Algorithms to Make CMS Deployment Decisions

It has been suggested that, for incidents which have ripple effects that lead to congestion and cause major delays upstream, computational aides or algorithms could be developed to help operators make decisions about both when to deploy additional CMS messages and how far upstream to deploy them. This suggestion may in part be due to the fact many Departments of Transportation, including Mn/DOT, use CMS displays to provide travel time information to specific locations. And, since it is possible to provide travel time information to specific locations then, perhaps, it would be possible to use the same approach when managing incidents and making decisions about when and where to deploy additional CMS messages.

However, there are important differences between the two situations. Travel time information is developed by comparing (1) historical data about how much time it typically takes to drive from one precisely known location (the location of the CMS display on which the travel time information is presented) to other precisely known locations (the locations for which travel time estimates are given), under various traffic conditions (i.e., at specific traffic volume and occupancy levels), with (2) current traffic data (i.e., current traffic volume and occupancy levels) that are obtained in real time from sensors (e.g., single loop detectors) embedded at various points between the known locations.

Considering the question of using computational methods to help make decisions about when and where to deploy additional CMS messages, the situation is different. It is true that the same kind of comparison that is made to predict the travel times between two specific known locations could be made for any pair of locations on the roadway system. It is also true that the locations of all CMS displays in the Mn/DOT system are already known. However, there is a problem with using computational methods or algorithms to help make decisions about when and where to deploy additional CMSs in response to particular incidents. While the location of each incident is provided rapidly to RTMC by FIRST units, State Patrol officers, or members of the public, an incident can occur *anywhere* on the approximately 400 miles of roadways that are monitored by the RTMC.

In order to be able to predict delays on the freeway for incidents that can occur anywhere on the system at any time, it would be necessary to have access to vast amounts of historical data. The needed information would have to indicate how much time is required to drive from the enormous number of possible locations at which incidents could occur to the various points at which CMS displays are located. In addition, it would be necessary to know how the travel time between those locations varies as a function of variations in traffic volumes and occupancy levels. Currently, such comparisons are not feasible with large roadway systems, and in particular with a system consisting of approximately 400 miles of roadways, such as that monitored by the RTMC.

Chapter 7
Conclusions

7.1 Introduction

This report describes Phase II of an investigation into the effectiveness and safety of traffic and non-traffic related messages presented on CMS displays. In Phase II we conducted two experiments that were directly comparable with two experiments carried out in Phase I. In both the Phase I and Phase II experiments, 120 participants drove, in a fully interactive PC-based STISIM driving simulator, for approximately 20 miles on a four-lane freeway before encountering a CMS target message. In the Phase I and Phase II experiments, there were low levels of traffic on the simulated roadway—the participants drove in free flow traffic conditions.

The target messages displayed in Phase II were clearer and less complex than those used in Phase I. In the first Phase II experiment, the target message advised drivers to leave the freeway at a particular exit and, in the second, the target message was a time-critical, non-site specific "Abducted Child" message. We investigated the comprehensibility of both messages and determined whether or not drivers reduced speed as they approached them.

Also in Phase II, we conducted a survey dealing with travel time information and other traffic-related information presented on CMS displays. In addition, we analyzed real-world traffic speed data obtained when CMS messages were deployed. Finally, we conducted observations at Mn/DOT's Regional Transportation Management Center (RTMC), focusing on the decision-making processes involved when traffic-related CMS messages are deployed.

7.2 Effect of Clarifying the "Use Thompson Exit" Message

In the first Phase I experiment, the target message was a time-critical, site-specific, CMS, which read "Crash/ At Wyoming Ave/ Use Thompson Exit." In the first Phase II experiment, the first and second lines of this target message were changed to "Road Closed/Crash Ahead"—but the third line was left unchanged. The changes to the first two lines make the message more explicit in indicating that there is a problem on the freeway. In addition, by omitting the specific location at which there is a problem, the message reduced the likelihood that drivers would make a mistake about where they should exit the freeway.

When we compared the responses of the participants to the "Thompson Exit" message in this experiment with the responses in the comparable Phase I experiment, we found that the changes made to the message had a considerable impact. In the first Phase I experiment, 67 of 120 participants (55.8%) took the Thompson Exit. In contrast, in the first Phase II experiment, 112 of the 120 participants (93.3%) took the Thompson Exit. A statistical comparison, using the Chi-Square Test, showed that the increase in the number of participants who took the Thompson Exit in Phase II was highly significant.

7.3 Effect of Reducing the Complexity of the "Abducted Child" Message

In the second Phase I experiment, the target message was a time-critical, non-site specific CMS message, which read "AMBER Alert/Red Ford Truck/ MN Lic# SLM 509." The changes made to this message in Phase II were more than a simplification. In Phase II, all three lines of the target message were changed—the new message read "Abducted Child/Tune To/Radio 88.5 FM." The change to the first line is a clarification of the more obscure term "AMBER Alert." However, the changes to the second and third lines of the message alter the way in which a driver can obtain the remaining information. Instead of giving direct information about the specific vehicle involved in the child abduction, the Phase II CMS message, directs drivers to a radio station, where the specific vehicle information can be heard.

At the end of the second Phase I experiment, ten of the 120 participants (8/3%) were able to recall some vehicle information and at least five of the six letters and numbers on the license plate—only two participants could recall all of the information on the CMS correctly. When the Phase I participants were asked what 'AMBER Alert' meant, 32 of the 114 participants (28%) who responded to this question did not know what the term meant.

In Phase II, 86 of the 120 participants (71.7%) could remember enough information to enable them tune to 88.5 FM. The improvement in the number of participants who obtained sufficient information to respond to the message in Phase II is very impressive, as well as statistically significant. In addition, all 120 participants knew the meaning of the term "Abducted Child."

7.4 Reductions in Speed on the Approach to the Target Messages

In the Phase I experiments, we investigated reductions in speed on the approach to the target messages. We did this by comparing the speed of individual participants in two road segments. In the first segment, the participants were between 1,860 feet (566.9 meters) and 860 feet (262.1 meters) from the location of the CMS display on which the target message was presented—throughout this 1,000-foot (304.8-meter) segment, the participants were too far away from the target messages to be able to read them. In the second segment, they were between 860 feet (262.1 meters) and 0 feet (0 meters) from the target messages—in this segment, the participants were within the range where it is possible to read the messages.

In the first Phase I experiment, on the approach to the "Use Thompson Exit" message, 16 of 120 participants (13.3%) reduced speed by 2 mph (3.2 km/h) or more as they drove from the first segment on the approach, when they were too far from the target messages to be able to read them, to the second segment, when they were within the range where it is possible to read the messages. In the first Phase II experiment, 31 of the 120 participants (25.8%) reduced speed by 2 mph (3.2 km/h) or more between these segments on the approach to the target message. However, for more extreme speed reductions—i.e., speed reductions that were 5 mph (8.0 km/h) or more—the numbers were the same in Phase II and Phase I. Also, no Phase II participants reduced speed by 9 mph (14.5 km/h) or more, while there were four participants in Phase I who reduced speed by 9 mph (14.5 km/h) or more.

In the second Phase I experiment, on the approach to the "AMBER Alert," 26 of the 120 participants (21.7%) reduced speed by 2 mph (3.2 km/h) as they drove from the second segment to the third segment. In the second Phase II experiment, 28 of the 120 Phase II participants (23.3%) reduced speed by 2 mph (3.2 km/h) or more as they drove from the first to the second segment on the approach to the "Abducted Child" message. The numbers of participants who reduced speed were similar in all speed ranges, from 2 mph (3.2 km/h) to 14 mph (22.5 km/h), for the second Phase I and Phase II experiment.

If the speed reductions observed in the simulation experiments conducted in both Phase I and Phase II are representative of real-world driving behavior, then it is likely that some drivers in free flow conditions do slow down as they approach CMS messages. This may not be the case when traffic is congested and traffic speeds are typically slower. When traffic is already moving at slower speeds, individual drivers are less likely to need to reduce speed still further in order to read CMS messages.

7.5 Survey Results

After the participants completed the two Phase II experiments, they were asked to respond to a survey. The survey included questions about the value of travel time information, and other traffic-related information that may be presented on CMS displays. The participants were asked to use a seven-point scale to assess the usefulness of this information. The main findings were that: (1) information about traffic problems was rated as being very useful—the average rating for the 120 participants was very high (6.39 out of 7); (2) information about roadway maintenance schedules was also rated as being very useful—again the average rating was very high (6.42 out of 7); (3) travel time information was rated as useful—the average rating was 5.38 (out of 7), but, (4) the ratings for safety messages were mixed and, on average, somewhat negative.

7.6 Traffic Speed and Real-World CMS Messages

To explore the question of whether CMS messages affect traffic speeds in real world driving, we examined real-world speed data obtained by the RTMC when CMS messages were deployed. The data were obtained from double loop detectors in the Middle and Right Lanes of Southbound I-35W near 73rd Street. These double loop detectors are located a few hundred feet (between 100 and 300 feet) downstream from the nearest CMS display. If drivers reduce speed on the approach to this CMS display, then they may still be driving slower a few hundred feet after they have passed beneath it. These double loop detectors cannot be relied on to provide accurate *absolute* speed data—they have not been calibrated for five years. However, they should provide reliable *comparative* speed data. Because of the problems with the double loop detectors, it is not meaningful to use the data obtained with them to make direct comparisons with the data obtained in the simulator experiments. However, we were able to analyze the double loop detector data and determine whether or not there were reductions in traffic speed that were consistent with speed reductions that could be associated with the deployment of CMS messages.

We analyzed data obtained at the time that CMS messages were deployed in connection with six incidents that occurred in March and April of 2008. We compared data obtained on the day that each incident occurred with comparison data obtained at the same time of day one week later. In order for comparisons to be meaningful, several criteria needed to be met: (1) traffic volumes should be similar in the pre-deployment period on both the test day and the comparison day; (2) traffic volumes should be similar during the deployment period on both the test day and the comparison day; (3) traffic speeds should be similar in the pre-deployment period on the test day and the comparison day; and (4) traffic speeds should be similar in the pre-deployment period and the deployment period on the comparison day.

For five of the incidents at least one of these criteria was violated. The remaining incident involved a crash on the ramp at 90th Street that occurred on Wednesday April 16, 2008. For this incident, two consecutive CMS messages were deployed. Our analysis showed that during deployment of both the first message ("Incident on Ramp/At 90th St/Use Caution") and the second message ("Exit Ramp Closed/At 90th St/Use Other Routes") the traffic speeds for the middle lane *were* statistically significantly slower on the test day than they were on the comparison day (the differences were not significant for the right lane). This result is consistent with the suggestion that deploying CMS messages can lead to slower driving speeds in real-world driving. But it does not help to determine under what conditions (speed and traffic volumes) the deployment of CMS messages cause traffic to slow down—our analysis could not have done that given the limitations of the data from the doubleloop detectors (i.e., that they were located downstream from the nearest CMS display and had not been calibrated for five years).

7.7 Observations of RTMC Operations

We visited Mn/DOT's RTMC to observe the work process in the Operations Center during several morning and afternoon peak traffic periods. We also conducted interviews with RTMC personnel. We focused on traffic operations and the decision-making processes involved in deploying traffic-related CMS messages.

In the Operations Center, imagery is obtained, in real time, from approximately 430 surveillance cameras that cover approximately 400 miles of roadways in the Twin Cities metropolitan area. Information about incidents is provided by State Patrol officers, FIRST units, and members of the public. The traffic operations operator uses the surveillance cameras to find the best available view of the incident. The ability to verify incidents is important—the operator needs to have a direct view of an incident in order to monitor its status and manage the CMS messages associated with it. Depending on the specific details of an incident, the operator decides whether or not to deploy a message on the CMS display(s) upstream from the incident, to warn oncoming drivers of potential hazard. The operator may also decide to deploy messages on CMS displays located on roads feeding into the roadway on which the incident has occurred. The operator makes the decision whether or not to deploy a CMS message based on: (1) the severity of the incident, (2) the location of the incident on the road network, (3) where the incident has occurred relative to the roadway (i.e., whether it affects one or more lanes, or is on a shoulder), (4) current traffic conditions, (5) how the incident is likely to affect traffic flow, and (6) his or her knowledge and experience.

The operator monitors each new incident as well as other incidents that occurred earlier. When a State Patrol officer and/or a FIRST responder arrives, the status of an incident may change—more lanes may be blocked, or an incident initially confined to the shoulder may encroach into the traffic lanes. The operator monitors incidents as they evolve, modifying the text of the CMS message(s) as necessary. The operator determines whether there are reductions in the speed of oncoming traffic. If there are reductions in speed upstream from an incident, the operator may deploy additional CMS messages still further upstream, or on feeder roads. Decisions whether or not to deploy additional CMS messages depend on how much of a ripple effect an incident is likely to have. In peak traffic periods, ripple effects are more likely and traffic delays are likely to propagate at faster rates. [It has been suggested that algorithms might be developed to help operators make decisions about deploying additional CMS messages, as the traffic density increases and traffic speed declines. However, incidents can occur *anywhere* on the approximately 400 miles of roadways monitored by the RTMC. To predict delays for any incident, it would be necessary to have access to vast amounts of historical data—data indicating the time required to drive from the enormous number of locations at which incidents could occur to the locations of CMS displays, and how that travel time varies with variations in traffic volumes and occupancy levels. Currently, predictive algorithms for incidents are not feasible for large roadway systems, such as that monitored by the RTMC.]

During our visits to the Operations Center, there were relatively few incidents. We observed that the operators responded to the incidents rapidly and managed them very efficiently. Sometimes in peak periods, particularly when there is poor weather, there are more incidents and, consequently, it is considerably more difficult to manage them. However, we believe that the decision-making processes that the RTMC Operations Center personnel currently have in place are sound and very efficient.

7.8 Summary and Concluding Remarks

With regard to time-critical, site-specific, CMS messages, like the "Use Thompson Exit" messages tested in Phase I and Phase II, it is clear that clarifying their content will lead to significantly more participants taking the advice they provide—which is what occurred in the Phase II experiment.

With regard to the time-critical, non-site specific, CMS messages, the dramatic improvement in the numbers of participants obtaining sufficient information to act on the Phase II message was striking. When Phase I of the investigation was conducted in 2003, Mn/DOT was using the term "AMBER Alert" in the first line of these messages. However in 2007, when Phase II was conducted, Mn/DOT was already using the term, "Abducted Child," that was used in the Phase II message. The results obtained in the Phase II experiment, with "Tune To/ Radio 88.5 FM" in the second and third lines of the message, strongly suggest that making this further change to "Abducted Child" message would be beneficial.

We are aware that this recommended change might be met with resistance. However, as we mentioned in our Phase I report (Harder et al., 2003), when the "Abducted Child" message includes the vehicle description and license plate number, it is relatively difficult for drivers to retain the information. As a number of investigators (e.g. Reitman, 1971; and Shiffrin, 1973) have shown, rapid forgetting occurs because of both decay and interference. Strategies for improving retention, such as rehearsal and repetition, would be helped if the "Abducted Child" CMS message omitted information that is hard to remember, like the vehicle details and license plate number, and replaced it with information which is relatively easy to encode, like the radio call sign used in the CMS message in the Phase II experiment. On tuning to the radio station, drivers would hear the "Abducted Child" message. This message, which would include the vehicle description and license plate number, could be repeated frequently. The repetition would make it far more likely that the vehicle description and license plate number would be moved from working memory to long-term memory, where drivers could retain it and access it for a much longer period of time. Then, it is far more likely that drivers would recognize the vehicle involved in the "Abducted Child" incident.

The suvey conducted after the participants had completed the Phase II experiments indicated that drivers think that using CMS dispalys to present information about traffic problems and roadway maintenance schedules is very useful. They also thought that travel time information was useful. In contrast, their responses to seeing safety messages on CMS displays were mixed.

The issue of whether the deployment of CMS messages causes traffic to slow down remains unsettled. It is clear, as in the case of the two-phase "AMBER Alert," reported in The San Francisco Chronicle (Lee, 2002), that CMS messages *can* cause severe reductions in speed. Also, as mentioned above, in the simulation experiments conducted in Phase I and Phase II, some participants reduced speed as they approached the CMS messages—they did this in free flow driving conditions. This finding suggests that similar reductions in speed could occur in real world driving in free flow conditions. However, when traffic is congested speeds are typically slower and drivers are less likely to need to reduce speed still further so that they can read CMS messages. As mentioned earlier in this report, Huey and Margulici (2006) attempted to determine whether or not traffic slowed when messages providing travel time information were presented on CMS displays on I-80 in Emeryville and Berkeley, California—but their results were inconclusive. In Phase II of this investigation, we also analyzed real-world data obtained at the time that six incidents occurred and CMS messages were deployed on I-35W near 73rd Street, in Minneapolis. When we analyzed the data, there was only one case in which we found a reduction in speed consistent with the suggestion that the deployment of CMS messages leads to slower driving speeds. We know that the deployment of CMS messages can lead to real-world reductions in traffic speed, although the conditions under which this will occur have not been defined. However, we can say that reductions in speed will be kept to a minimum, and possibly avoided, if clear, unambiguous text in used on CMS messages.

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Appendix A
Post-Drive Questions

The questions that each participant was asked immediately after he or she completed the second experimental drive are presented on the following pages of this appendix.

Subject Number_____

Questions

Question #1: Can you please tell me what was written on the last Message Board over the road?

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Question #2: Can you remember any other signs that you saw during the drive?

Yes____ No____

[If the subject answers "Yes" to Question #2, go to Question #3

[If the subject answers "No" to Question #2, go to Question #8

Question #3: Can you please tell me what they said?

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Question #4: [If in answer to Question #3, the subject only remembers "Direction" signs, ask…] Did you see any signs giving any other information?

Yes____ No____

Question #5: [If the subject answers "Yes" to Question #4, ask…] Can you please tell me what they said?

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Question #6: [If in answer to Question #3, the subject only remembers the “Stalled Vehicle” signs, ask…] Did you see any signs giving directions?
Yes____ No____

Question #7: [if the subject answers “Yes” to Question #6, ask…] Can you please tell me what they said?

Question #8: What does “Abducted Child” mean?

Question #9: What would you do if you saw an “Abducted Child” sign?

Questions about the first scenario (Crash Ahead)

If the subject did not take the Thompson exit, ask him/her this question.

Question #10: Did you notice the sign at the end of the first test scenario?
Yes____ No_____

Question #11: [If the subject answers “Yes” to Question #9, ask…] What was the reason that you did not take the exit?

Appendix B
Post-Drive Survey

The questions asked in the survey completed by the 120 experimental participants after they finished driving the simulator are presented on the following pages of this appendix.

Subject Number_____
Survey Questions

Question #1: When you are driving on Metro Freeways, have you seen message boards that give travel time information—i.e., messages that tell you how much time it will take to get to a particular location or to a freeway?
Yes____ No____

If you answer "Yes" please continue with Question #2.
If you answer " No" please proceed to Question #4.

Question #2: How useful to you is travel time information? Please mark your answer on the scale which goes from 1 to 7—where "1" means "Not at all useful" and "7" means "Very useful."

Not at all Useful 1 2 3 4 5 6 7 Very Useful

Question #3: Does travel time information affect your stress level when you are driving? Please mark your answer on the scale which goes from 1 to 7—where "1" means "Greatly increases my stress level" and "7" means "Greatly reduces my stress level"

Greatly Increases My Stress Level 1 2 3 4 5 6 7 Greatly Reduces My Stress Level

Question #4: When you are driving on Metro Freeways have you seen message boards that give information about traffic problems ahead that could affect traffic speed—i.e., messages tell you that there is a "Crash Ahead" or "Congestion Ahead" or "Road Work Ahead" or "Stalled Vehicle Ahead"?
Yes____ No____

If you answer "Yes" please continue with Question #5.
If you answer " No" please proceed to Question #7.

Question #5: How useful to you is information about traffic problems? Please mark your answer on the scale which goes from 1 to 7—where "1" means "Not at all useful" and "7" means "Very useful."

Not at all Useful 1 2 3 4 5 6 7 Very Useful

Question #6: Does information about traffic problems affect your stress level when you are driving? Please mark your answer on the scale which goes from 1 to 7—where "1" means "Greatly increases my stress level" and "7" means "Greatly reduces my stress level"

Greatly Increases My Stress Level 1 2 3 4 5 6 7 Greatly Reduces My Stress Level

Question #7: When you are driving on Metro Freeways have you seen message boards that give safety messages—like "Buckle Up" or "Don't Drive Drowsy" or "Don't Drink and Drive"?

Yes____ No____

If you answer "Yes" please continue with Question #8.
If you answer " No" please proceed to Question #9.

Question #8: How useful to you are safety messages? Please mark your answer on the scale which goes from 1 to 7—where "1" means "Not at all useful" and "7" means "Very useful."

Not at all Useful 1 2 3 4 5 6 7 Very Useful

Question #9: When you are driving on Metro Freeways have you seen message boards that give information about roadway maintenance schedules—like "Road Closed Thru June 1" or "Road Closed June 19 Thru July 25"?

Yes____ No____

If you answer "Yes" please continue with Question #10.
If you answer " No" you have completed the survey.

Question #10: How useful to you is information about roadway maintenance schedules? Please mark your answer on the scale which goes from 1 to 7—where "1" means "Not at all useful" and "7" means "Very useful."

Not at all Useful 1 2 3 4 5 6 7 Very Useful