Studying the Vehicle Headway Issue and Its Impact on the Slow-Down Effect

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Tailgating is a dangerous driving behavior and is a major cause of rear-ended crashes. Finding effective means to help drivers maintain proper vehicle headways and to warn and discourage tailgating behavior is thus of utmost importance to traffic management authorities. This project presented a human-factors study, consisting of a vehicle headway analysis and a questionnaire survey, which was aimed to identify the causes of tailgating and to find effective means for tailgating treatments. In the vehicle headway analysis, vehicle headways on specific segments of major highways in Rhode Island were examined. With tailgating phenomenon confirmed from the analysis, the study next searched means to mitigate tailgating behavior. A questionnaire survey was conducted to find the leading causes of tailgating. Drivers’ preferences on several tailgating treatments were surveyed. The results of the survey indicated that the majority considered “tailgating” a serious offense. Most of them, however, did not know what the proper vehicle headway was when driving on highways. Among the few different tailgating treatments, most preferred the one where equal-distanced horizontal bars were used as reference markings. They also indicated that properly designed dynamic message signs and fixed signs using both graphics and words could help them better understand the proposed tailgating treatment systems.
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1. INTRODUCTION

This project conducted a human-factors study on the causes of tailgating and possible means for tailgating treatments. It was aimed to facilitate a more efficient and safer driving on highway by reducing accidents caused by tailgating.

The National Highway Traffic Safety Administration (NHTSA) defines “Aggressive driving” as “an individual committing a combination of moving traffic offenses so as to endanger other persons or property.” More specifically, speeding, tailgating, weaving in and out of traffic, running red lights, using emergency breakdown lane for travel, or any combination of these activities are generally considered aggressive driving.

In Rhode Island, “Aggressive Driving” is defined as operating a motor vehicle in violation of any speed law and a violation of two or more of traffic law provisions. While many driving patterns are considered aggressive, tailgating is one of the most dangerous driving behaviors and is a major cause of rear-end crashes. The National Highway Traffic Safety Administration (NHTSA) research has reported that about 32 percent of the annual fatalities in motor vehicle crashes were speed-related and at least one of the drivers involved in the crash exceeded the posted speed limit or was driving too fast for the prevailing conditions.

In Rhode Island, speeding accounts for 52 percent of all statewide fatalities, 20 percent higher than the national average, and causes more than 40 fatalities per year since 2002. Out of an annual average of 6.3 million automobile accidents in the US in the past few years, rear-end collisions ranked as the highest, with about 2.5 million
cases per year. The two main causes of rear-end crashes are driver-inattention and tailgating while the latter is the major contributing cause with a deadly consequence.

Finding effective means to help drivers maintain proper vehicle headways and to warn and discourage tailgating behavior is thus of utmost importance to traffic management authorities. As the most dangerous one of all the aggressive driving patterns, “Tailgating” is defined as following too closely—interval between vehicles. Therefore, maintaining safe following distances is the most effective way to avoid tailgating.

Vehicle headway, or the headway between vehicles, is defined as the time between two vehicles passing the same point. Many studies have demonstrated that following distances depend on a wide range of factors such as driver behavior, traffic condition, road condition, roadway design, state law and regulation, and personality [1, 2, 3, 4, 5]. Tailgating treatments such as advisory signs and road markings have been tested in some studies. These treatments have provided drivers with information regarding following distance and showed good results. To mitigate rear-end collisions caused by tailgating, Lertworawanich [6] conducted a study to estimate safe car-following distance for a speed range from 80 km/h to 120 km/h, and developed the “dot” tailgating treatment marking to implement the findings. Rama & Kulmala [7] conducted a field study in Finland investigating the effects of variable message signs (VMS) on driver’s car-following behavior. Results showed that those warning signs reduced the mean speed and increased following distance. Pennsylvania DOT has successfully conducted a tailgating treatment program that was honored with a 2001
National Highway Safety Award [8]. Tailgating has dropped a significant 60% on a portion of US route 11 after equipping with reflective dots on the roadway and pavement markings and signs that help motorists gauge their following distances. Minnesota DOT and Public Safety piloted a similar project in 2006 by employing similar engineering elements from the Pennsylvania program: elliptical pavement dots, informational signs, and a strong public information campaign [9]. On a section of State Highway 55, the average gap increased from 2.36 to 2.62 seconds, or 22.9 feet.

To gain insights on tailgating issue, explore effective means to warn and discourage such behavior and identify the causes of tailgating, a multi-stage study was conducted for this purpose. It started with an extensive literature review to identify leading causes to tailgating and existing practices in tailgating treatments. A vehicle headway analysis was then conducted to evaluate tailgating behaviors on Rhode Island highways. A survey was employed to identify the causes of tailgating and to assess drivers’ understanding of tailgating and their preferences regarding several proposed tailgating treatments. It intends to find an effective tailgating treatment for the state of Rhode Island.

2. RESEARCH OBJECTIVE AND GOAL

The proposed study will examine the vehicle headway issue and its impact on the slow-down effect that is often observed on vehicles approaching in-service dynamic message signs. The purpose of this research is to help achieve the mission stated in
the Rhode Island Strategic Highway Safety Plan to reduce fatalities and serious injuries caused by aggressive driving. The proposed research is consistent with the URITC Theme “Connectivity through Sustainable Transportation Systems.” It is aimed to facilitate more efficient and safer driving on highway by reducing accidents caused by aggressive driving, namely, tailgating. It will identify the major causes of tailgating and assess various features that might impact the effectiveness of using tailgating treatment systems such as roadside reference marks, pavement markings, fixed signs, and variable/dynamic message signs. Four areas of interest were defined in order to create a comprehensive and methodical approach:

1. Identify the characteristics of existing vehicle headway management and tailgating treatment systems and evaluate their capabilities and limitations through an extensive review of literature and existing studies.

2. Assess vehicle headway behaviors on Rhode Island highways through analysis of highway surveillance videos in the term of vehicle headway.

3. Find out leading causes of tailgating through questionnaire survey and propose feasible vehicle headway management and tailgating treatment systems for Rhode Island. Compare both existing and proposed systems with respect using roadside reference marks, pavement markings, fixed signs, and variable/dynamic message signs.
4. Analyze the survey results and recommend one or more effective vehicle headway management and tailgating treatment system for Rhode Island highways to help reduce injuries and fatalities caused by rear-end crashes.

3. LITERATURE REVIEW

An extensive literature search was conducted on available transportation publications, manuals, articles, and past studies regarding vehicle headway issue and tailgating treatment systems. It encompassed documents both in the United States and international, and is presented in the following sections. Topics covered include accident risk caused by vehicle headway issue, driver’s reaction time, factors effect vehicle headway, feasibility of using treatments to warn and discourage tailgating and any “best practices” adopted by state DOTs or traffic management agencies in treating the vehicle headway and tailgating problem, and the use of graphics on traffic signs.

3.1 Accident risk caused by vehicle headway issue

In Rhode Island, “Aggressive Driving” is defined as operating a motor vehicle in violation of any speed law and a violation of two or more of traffic law provisions [10]. The National Highway Traffic Safety Administration (NHTSA) research has reported that about 32 percent of the annual fatalities in motor vehicle crashes were speed-related and there were 12,000 persons killed in these crashes every year [11]. In
Rhode Island, speeding accounts for 52 percent of all statewide speed-related fatal crashes, that is 20 percent higher than the national average, and causes more than 40 fatalities per year since 2002. Out of an annual average of 6.3 million automobile accidents in the US in the past few years, rear-end collisions ranked as the highest, with about 2.5 million cases per year. The two main causes of rear-end crashes are driver-inattention and tailgating while the latter is the major contributing cause with a deadly consequence.

The term “headway” usually is defined as the time between the front bumper of one vehicle and the front bumper of the next [12], while in this study, vehicle headway that of the most interest is the time interval between the back bumper of one vehicle and the front bumper of the next, more precisely, called gap.

3.2 Drivers’ reaction time

Simple reaction times are often less than 1 second, but decision reaction times often takes much longer [13, 14]. Driver’s perception time varies from 0.5 second for simple situations to 4 seconds for complex situations and the perception-reaction time in braking is about 2.5 seconds [15]. According to this, quantified safe following distances have been written into rules of the road. It varies from states to states, but mostly in the forms of “2-second rule” or “3-second rule” that drivers should keep at least 2/3 seconds vehicle headway from the vehicle ahead driving in the same direction.
3.3 Factors effect vehicle headway

Many studies have demonstrated that following distances depend on a wide range of factors such as driver behavior, traffic condition, road condition, roadway design, state law and regulation, and personality [1, 2, 3, 4, 5]. And a lot of car following models were developed to describe the interaction between adjacent vehicles in the same lane, and even the whole traffic dynamics. However, few of them provided information about major factors effected following distance and could lead to tailgating.

3.4 Feasibility of using vehicle headway treatment

Tailgating treatments such as advisory signs and road markings have been tested in some studies. These treatments have provided drivers with information regarding following distance and showed good results. To mitigate rear-end collisions caused by tailgating, Lertworawanich [6] conducted a study to estimate safe car-following distance for a speed range from 80 km/h to 120 km/h, and developed the “dot” tailgating treatment marking to implement the findings.

Rama & Kulmala [7] conducted a field study in Finland investigating the effects of 2 variable message signs (VMS) on driver’s car-following behavior. The signs warned of slippery road conditions and to keep a minimum following distance. The study was performed as a before-and-after experiment at 3 test sites with an after period covering 2 winter seasons. Results showed that the slippery road conditions sign reduced the mean speed on slippery roads by 1-2 km/hour in addition to the
decrease caused by the adverse road conditions. The minimum following distance sign reduced the proportion of cars with following distances less than 1.5 seconds, in addition to a speed reduction of 1 km/hour.

Several tailgating treatment programs were conducted by the state DOTs. The most successful one is the PENNDOT’s Tailgating Treatment Program (Safety Improvements) which then honored with a 2001 National Highway Safety Award. On a portion of US route 11 that previously experienced high rates of tailgating, aggressive driving and tailgating has dropped a significant 60% after equipping with reflective dots on the roadway and pavement markings and signs that help motorists gauge their distance behind moving vehicles [8]. The average daily traffic of the targeted area of route 11 is around 13,600. Before implementation there were 135 crashes a year costing approximately $1.9 million. Afterwards, yearly crashes decreased to 60 at a reduced cost of $1.3 million. The cost of implementation in the first year is estimated at just over $11,000, including enforcement. After eight to nine months, statistics indicated that crash reductions remained fairly constant, pointing to the success of the program. Figure 3.1 Tailgating Treatment in Pennsylvania with painted dots and fixed signs displays the tailgating treatment system in PENNDOT program.

Given the successes, relatively low implementation cost and the measurable benefits of PENNDOT program, Minnesota DOT and Public Safety piloted a similar project in 2006. The project was viewed as a tool to educate motorists on how to identify and maintain a minimum safe following distance, and ultimately reduce rear end crashes. Minnesota used similar engineering elements from the Pennsylvania
program: elliptical pavement dots, informational signs, and a strong public information campaign. A section of State Highway 55 in Wright County was used to paint 94 elliptical dots, spaced 225 feet apart, along a two-mile segment of the rural, single-lane, 55 mile-per-hour roadway. Vehicle headway data collected prior to and after installation of the pavement marking dots and signs showed that at the mid-point of the marking location, the average gap increased from 2.36 to 2.62 seconds, or 22.9 feet [9].

Figure 3.1 Tailgating Treatment in Pennsylvania with painted dots and fixed signs Source: http://www.roadwaysafety.org/RSF%20Reporter/1st_Qtr_03/penndot.htm

These existing tailgating treatment systems using a combination of roadside reference marks, information signs and pavement markings are highly effective in maintaining safe following distances and reducing fatalities and serious injuries caused by tailgating. However, it is still feasible to seek further improvements on current systems. Michael, Leeming, & Dwyer [16] implemented a method to collect
tailgating data in an urban setting and gained some insights into the effectiveness of 2 hand-held roadside signs admonishing drivers not to tailgate by producing reliable data on over 25,000 drivers. They found that one of these signs (with a reference to crashes) had a significantly positive impact on drivers' tailgating behavior comparing to another one, which expanded the average drivers following headway from 2.11 seconds when the sign was absent, to 2.29 seconds when the sign was present.

3.5 Use of graphics on traffic signs

The use of graphical images to help understanding of roadway signs is a common practice and has been shown in several studies to provide numerous advantages over text only messages alone. Graphic aided messages are more easily and quickly identified compared to messages containing only text, and graphics can be recognized from a further distance. The use of graphics or symbols on DMS signs has been employed in many European countries such as Germany and Spain but has not yet gained widespread popularity in the United States.

In comparison with text-only messages, graphic-aided messages can be identified easier, faster, and from a farther distance. They are seen better under adverse viewing conditions, and understood better by people who cannot understand the language in the text. Furthermore, graphics are more effective at conveying information to motorists who cannot understand the language in text messages [17]. Another study investigating performance on tasks with written or verbal instructions found that graphics alone led to quicker reaction times but accuracy was increased with the
addition of words [18]. Several studies have found that graphically presented information produced faster responses than words [19,20].

4. METHODOLOGY

In order to examine the tailgating behavior on Rhode Island highways, identify the causes of tailgating, and to assess driving subjects’ preferences to different tailgating treatment systems, two approaches were employed in this human-factors study consisting of a vehicle headway analysis and a computer based questionnaire survey. The vehicle headway analysis collected highway surveillance videos and assessed the tailgating behavior. The questionnaire survey studied driving subjects of both genders within three distinct age groups (18-40, 41-60, 61+) and collected their opinions and preferences toward cause of tailgating and tailgating treatment designs.

4.1 Vehicle headway analysis

To examine the tailgating behavior on Rhode Island highways, highway traffic surveillance videos were analyzed. For this study, Rhode Island Department of Transportation provided two-week’s of traffic surveillance videos that captured all-lane traffic on three specific segments of major highways in December 2008. They were I-95 at Detroit Ave, I-195 at Rte. 114, and I-295 North at Exit 6.
4.1.1 Video collection

Video clips collected on each day during both rush hour and non-rush hour were analyzed. Rush hour videos were recorded between 7:30am and 8:00am on weekdays (from Monday to Friday) while non-rush hour videos were between 10:00am and 10:30am. From each of the 30-minute video clips, five one-minute sections were randomly selected for analysis.

4.1.2 Vehicle headway analysis

By randomly setting up a reference line, based on the time stamp embedded in the video, time for the front bumper of each vehicle reached that reference line was recorded (see Figure 4.1 Data collection in vehicle headway analysis). By calculating the time intervals between two vehicles next to each other in the same lane, vehicle headways measured in time were recorded for all vehicles appeared in videos.

Figure 4.1 Data collection in vehicle headway analysis
According to the quantified safe following distances that have been written into rules of the road, vehicles examined in the video were classified as 3-second tailgaters, 2-second tailgaters, as well as 1-second tailgaters and non-tailgaters. For example, if a vehicle’s headway was in between 2 and 3 seconds, it was marked as a 3-second tailgater; if a vehicle’s headway was in between 1 and 2 seconds, it was marked as a 2-second tailgater; so it was 1-second tailgater; non-tailgaters were defined as those driving with a vehicle headway more than 3 seconds. The percentages of them in total vehicles counted were calculated for comparison.

The total number of 1-second tailgater, 2-second tailgater, and 3-second tailgater was the number of vehicles who broke 3-second rule. Both 1-second tailgater and 2-second tailgater broke 2-second rule.

To find out if time of the day was a significant factor in effecting vehicle headway issue, more specifically, amount of vehicles who broke 3-second and 2-second rule, a hypotheses test using paired t-test was employed for all three highway segments between rush hour and non-rush hour:

\[ H_0 : \mu_d = 0 \]

\[ H_1 : \mu_d > 0 \]

Since all the three highway segments have 4 lanes, to fully assess tailgating issue in Rhode Island, the data collected from the video was broke down by lanes and conducted comparisons among them.
4.2 Questionnaire survey

To help identify the causes of tailgating, a computer based questionnaire survey was designed and deployed. It was also designed to gain insights about drivers’ understanding, interpretation and preference of various design features of tailgating treatment that could help mitigate tailgating behavior.

4.2.1 Design of the questionnaire survey

It was a computer based electronic survey containing 19 single/multiple choice questions. These 19 questions could be divided into 3 groups: causes of tailgating, to find out drivers’ perceptions of tailgating and its causes and effects; vehicle headway, to identify drivers’ behaviors when following other vehicles or being followed; tailgating treatments, to assess drivers’ preferences regarding different proposed treatment systems. A tailgating treatment system includes: reference marking (pavement marking, roadside marking), and advisory message signs (dynamic message signs, variable message signs, or fixed road signs).

Prior to developing the computer based questionnaire survey, research was required to establish various criteria to investigate through the help of the computer based survey. This research required the review of past literature detailing vehicle headway issue and the use of different types of tailgating treatment systems. In order to develop the survey, suggestions were also taken from other sources, including officials from the Rhode Island Department of Transportation (RIDOT) and University of Rhode Island Transportation Center (URITC). Some reference markings
and advisory message signs of proposed tailgating treatment systems in the survey were adopted from existing tailgating treatments in the US as well as those currently used in several European countries. Figure 4.2 Reference markings and advisory message signs used in the survey shows reference markings and advisory message signs used in the questionnaire survey.
The questionnaire survey was designed using Microsoft PowerPoint® and Visual Basic macros to record the subject’s answers to each set of questions. Each question in the survey required subjects to choose single or multiple answers.

The computer based electronic survey contained a total of 32 slides with 19 questions designed to collect drivers’ opinions on questions of 3 categories. Causes of tailgating; vehicle headway, to identify drivers’ behaviors when following other vehicles or being followed; tailgating treatments, to assess drivers’ preferences regarding different proposed treatment systems.

a. **Causes of tailgating:**

6 questions were presented including major causes of crashes, reasons of following other cars, frequency of following other cars, reasons of not following other cars, definition of tailgating, and major causes of tailgating.

The purpose is to find out driver’ perceptions of tailgating and its causes and effects
1. Which of the following would you consider as major contributing factors to crashes? Rank the TOP 3 by inputting 1,2,3 respectively.

- Road rage
- Distraction
- Tailgating/insufficient headway
- Running red lights
- Speeding
- Changing lanes without signaling
- Obstruction of passing vehicles
- DUI
- Mechanical failures
- Road conditions
- Poor weather
- Poor visibility
- Confusing road signs

Next Question

Figure 4.3 Major causes of crashes

2. Why would you intentionally follow other cars closely while driving on highways?

- (A) It is easier to maintain speed
- (B) It is safer
- (C) It is less likely to get a speeding ticket
- (D) I don’t do that

Next Question

Figure 4.4 Reasons of following other cars
3. Do you intentionally follow other cars closely while driving on highways?

- (A) Always
- (B) Sometimes
- (C) Never

Figure 4.5 Frequency of following other cars

4. Why would you not follow other cars closely while driving on highways?

- (A) It obstructs my view
- (B) Others drive too slow
- (C) It is safer
- (D) It is against the law

Figure 4.6 Reasons of not following other cars
26

5. Which of the following would best describe tailgating?

- (A) Following too close to the vehicle ahead
- (B) Insufficient following distance
- (C) Staying as close as possible to the vehicle ahead
- (D) I don't understand what tailgating means

Figure 4.7 Definition of tailgating

6. Which of the following could cause you to tailgate while driving on highways? Mark all that apply.

- Heavy traffic
- Slow car ahead of my vehicle
- In a hurry
- Poor visibility
- Distraction
- Weather conditions
- Hypermiling

Figure 4.8 Major causes of tailgating

*Hypermiling:* the act of driving using techniques that maximize fuel economy. People sometimes draft behind trucks to reduce their wind resistance, increasing the possibility of a rear-end collision.
b. **Vehicle headway:**

8 questions were presented to identify drivers’ behaviors when following other vehicles or being followed. Subjects were first asked their reactions when being tailgated, acknowledgement of proper vehicle headway, and importance of keeping safe vehicle headway. Then, to get qualitative opinions about tailgating behavior, they were asked about frequency of keeping safe vehicle headway, and drivers’ behavior in maintaining following distance. The quantitative opinions were obtained by asking them vehicle headway maintained while driving on highway measured in both *second* and *car length*, and the preferred way to measure vehicle headway.

Depending on which way most of driver subjects preferred, the answers to the associated “how many vehicle headway maintained” question could be used to assess their tailgating behavior.

![7. How would you react if you were followed too closely? Mark all that apply.](image)

Figure 4.9 Driver’s reactions when being tailgated
8. Do you know what is the proper vehicle headway (following distance) to maintain while driving on highways?

- (A) Yes
- (B) No

Figure 4.10 Drivers’ acknowledge of proper vehicle headway

9. How important is it for you to keep a safe vehicle headway (following distance) while driving on highways?

- (A) Very important
- (B) Important
- (C) Average
- (D) Slightly important
- (E) Not important

Figure 4.11 Importance of keeping safe vehicle headway
10. Do you maintain a safe vehicle headway (following distance) while driving?

- (A) Always
- (B) Most of the time
- (C) Sometimes
- (D) Rarely
- (E) Never

Figure 4.12 Frequency of keeping safe vehicle headway

11. Which of the following statements best describes how you drive while following other vehicles on highways?

- (A) I maintain the maximum possible following distance.
- (B) I maintain a proper following distance.
- (C) I tend to follow vehicles closely

Figure 4.13 Drivers’ behavior in maintaining following distance
12. How much vehicle headway (following distance) in seconds would you maintain between your car and the vehicle in front of you while driving 60 mph on highways?

(A) One second  
(B) Two seconds  
(C) Three seconds  
(D) More than three seconds  
(E) I don't know

Figure 4.14 Vehicle headway (in second) maintained while driving on highway

13. How much distance would you maintain between your car and the vehicle in front of you while driving 60 mph on highways?

(A) One car length  
(B) Two car lengths  
(C) Three car lengths  
(D) Four car lengths  
(E) Five car lengths  
(F) Six car lengths  
(G) 7-10 car lengths  
(H) 11-15 car lengths  
(I) I don't know

Figure 4.15 Vehicle headway (in car length) maintained while driving on highway
c. Tailgating treatments:

5 questions were presented to assess drivers’ preferences regarding different proposed treatment systems.

Depending on which kind of reference markings each subject chose for Question 16, Question 17-19 were displayed for him/her with that reference marking on.
15. Which of the following would you consider effective in helping drivers maintain safe vehicle headway (following distance)?

- (A) Advisory message signs about safe following distances
- (B) Reference markings on the road demonstrating the exact distances to maintain
- (C) Roadside markings demonstrating the exact distances to maintain
- (D) A and B
- (E) A and C

Figure 4.17 Vehicle headway treatment design

16. Which of the following would be most effective in helping you maintain a proper vehicle headway?

- (A) Painted dots
- (B) Painted arrows
- (C) Neon panels
- (D) Bars

Figure 4.18 Reference markings for vehicle headway treatment
17. Which of the following signs would be easiest to understand?

(A) KEEP MINIMUM 2 DOTS APART

(B) KEEP MINIMUM 2 DOTS APART

(C) SAFE DISTANCE 2 DOTS

(D) SAFE DISTANCE 2 DOTS

Figure 4.19 Fixed signs for vehicle headway treatment

18. Which of the following signs would be easiest to understand?

(A) KEEP MINIMUM 2 DOTS APART

(B) KEEP MINIMUM 2 DOTS APART

(C) SAFE DISTANCE MINIMUM 2 DOTS

(D) SAFE DISTANCE MINIMUM 2 DOTS

Figure 4.20 Fixed signs for vehicle headway treatment
4.2.2 Authorization for the electronic survey

Due to the necessity of the use of human subjects participating in the study, permission for the completion of the research was required from the Institutional Review Board (IRB) at the University of Rhode Island. The IRB must be contacted in any study involving human factors, in order to ensure that human subjects will not be harmed in any way during the course of the research. As conditions of approval of the study, the IRB required that consent forms be read and filled out by all participants in the study acknowledging that they had been informed as to the purpose and potential benefits of the research, possible risks or any discomforts they might experience, and all contact information of individuals they could direct questions to, along with a
statement informing them of their ability to stop and quit the survey at any time, if they wished to do so.

In this survey, the consent form was in electronic form on the second slide of the survey, subjects would start doing the survey by pressing the “Start” button if they agreed to take the survey.

4.2.3 Recruitment of subjects

Due to the large number of subjects needed to take part in the research, various methods were used to recruit a wide variety of drivers to take the survey. All drivers were eligible to participate as long as they held a valid U.S. driver’s license, but they did not need to drive on a regular basis in order to take the survey. To recruit younger driving subjects, members of the research team attended several on campus events at URI attended by university students and staff. A good amount of subjects were obtained using this method.

To recruit older drivers, other methods were employed. An event was held at the Warwick Mall to draw subjects to participate in the study. Flyers and posters (see Figure 4.22 Tailgating Public Survey poster) were displayed at the mall to inform shoppers of the research and invite them to participate. Although some elder drivers participated in the research during the mall event, the majority of elder drivers had to be recruited using other methods. Researchers also visited Kathleen M. Mallon Outreach Center of University of Rhode Island on a daily basis for a week to recruit their volunteers all of whom were older drivers.
The recruiting process was well controlled to make sure the participants’ demographic statistics as close to Rhode Island demographic statistics as possible.

![Tailgating Public Survey poster](image)

**Figure 4.22 Tailgating Public Survey poster**

4.2.4  **Incentives for participation in the study**

To provide an incentive for subjects to participate in the research, a variety of small gifts were handed out to subjects after their completion of the survey. These items included calculators, back packs, and pens. Some of the items were stitched with the URI Transportation Center logo. The cost of the items varied from $2 to $5 each.
4.2.5 Completion and administration of the survey

To gather responses from various driver subjects, the survey was given to and completed by volunteer subjects who possessed valid drivers’ licenses. The survey was conducted at several different locations throughout the state including the University of Rhode Island, the Warwick Mall as well as various locations in the town of South Kingstown, close by the URI campus. The variety of locations was selected to ensure that a broad sample of the driving population was obtained (see Table 4.1 Participants’ demographic statistics). After arrival, subjects were greeted by a member of the research team and given information about the survey and the study. They were asked if they had any questions regarding the study, and invited to take part in the research if they so chose. All subjects read and completed an electronic consent form approved by the IRB (Institutional Review Board) to acknowledge that they sufficiently understood the research and agreed to participate in the study.

<table>
<thead>
<tr>
<th>Age groups</th>
<th>Gender</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>18-40 yrs. old</td>
<td></td>
<td>50 subjects</td>
<td>41 subjects</td>
</tr>
<tr>
<td>41-60 yrs. old</td>
<td></td>
<td>31 subjects</td>
<td>41 subjects</td>
</tr>
<tr>
<td>61+ yrs. old</td>
<td></td>
<td>22 subjects</td>
<td>25 subjects</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>103 subjects</td>
<td>107 subjects</td>
</tr>
</tbody>
</table>

Subjects began the PowerPoint survey via a laptop computer. Two introductory slides (including the consent form) were shown prior to answering the questions (see Figure 4.23 Introductory slideFigure 4.24 Introductory slide with consent form).
The slides informed the subject of the goal of the research study and reminded them again of the contacts and the numbers where researchers could be reached in case of any questions the subject had related to the research or any concerns they wished to formally express. After viewing the introductory slides, the subject began the survey by clicking on the “Start” button. After selecting a choice, the subject advanced to the next slide by clicking the “Next Question” button appearing at the bottom of each slide. Subjects were not timed while they completed the survey so they could take as much time as they needed to answer a question. Researchers oversaw the completion of the survey and answered any questions the subject had as they arose.
After all the survey questions had been answered, the subject completed a demographic information form to record their age and gender information. By clicking on the “Submit” button at the bottom of the slide, the information would be recorded and the subject was allowed to exit the survey (see Figure 4.25 Demographic information form). The subject’s answers and demographic information were automatically stored as text files (see Figure 4.26 Subjects’ answers stored as text files) and entered into an MS Excel® database to be analyzed in the final phase of the project. The confidentiality of participants was ensured through the use of a locked room to store all consent forms and the computer which contained individual subject information.

![Questionnaire on Vehicle Headway and Treatments](image)

Figure 4.24 Introductory slide with consent form
Personal Data

First Initial: 
Last Initial: 
Age: 18 - 40 41 - 60 61 and above 
Gender: Male Female 
Native language: English Spanish Other: 
Highest Education: Elementary School Middle School High School College Post-Graduate 
Are you color blind: Yes No 
Do you wear glasses/contacts: Yes No 

Submit

Figure 4.25 Demographic information form

Figure 4.26 Subjects’ answers stored as text files
5. RESULTS AND DISCUSSION

5.1 Vehicle headway analysis

The time for each vehicle sampled was recorded in Excel. Vehicle headways were calculated and analyzed. An Excel worksheet is shown in Figure 5.1 Vehicle headway analysis Excel worksheet.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>955 Time: 12/6/08 Mon 7:30am-8:06am</td>
<td>Sample 5s Intvl</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Total Vehicle</td>
<td>658</td>
<td>Percentage</td>
<td>Assume average vehicle length is 15 feet and average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td>1 sec Tailgater</td>
<td>247</td>
<td>37.54%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>2 sec Tailgater</td>
<td>451</td>
<td>68.54%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td>3 sec Tailgater</td>
<td>535</td>
<td>83.31%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results regarding vehicle headway analysis are shown in Table 5.1 Summary of vehicle headway analysis. As noted from the table, there were around 70%-80% vehicles with less than 3 seconds of headways, about 60% vehicles with less than 2 seconds of headways, and around 30% to 40% vehicles with less than 1 second of headways during rush hours. The only exception was I-195 during rush hours which
had lower percentages (about 60%, 40%, and 20%, respectively) because of lower vehicle volume in videos.

During non-rush hours, there were still about half of the vehicles were with less than 3 seconds of headways, about 30% to 40% vehicles were with less than 2 seconds of headways, and around 20% vehicles maintaining less than 1 second of headways.

Comparing to rush hours’ results through paired t-tests (with significance = 0.05), significant reductions in both percentages of vehicles who broke 2-second and 3-second rules were observed at all three locations during non-rush hours since all p-values were less than significance value.

Table 5.1 Summary of vehicle headway analysis

<table>
<thead>
<tr>
<th>Highway sections</th>
<th>I-95 @ Detroit Ave</th>
<th>I-195 @ Rte. 114</th>
<th>I-295 N @ Ex. 6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Time of Day</td>
<td>Rush hour</td>
<td>Non-rush hour</td>
</tr>
<tr>
<td>Monday</td>
<td>1s tailgater</td>
<td>44.97%</td>
<td>25.00%</td>
</tr>
<tr>
<td></td>
<td>2s tailgater</td>
<td>17.99%</td>
<td>18.94%</td>
</tr>
<tr>
<td></td>
<td>3s tailgater</td>
<td>13.76%</td>
<td>16.67%</td>
</tr>
<tr>
<td>Tuesday</td>
<td>1s tailgater</td>
<td>38.85%</td>
<td>23.61%</td>
</tr>
<tr>
<td></td>
<td>2s tailgater</td>
<td>20.69%</td>
<td>18.01%</td>
</tr>
<tr>
<td></td>
<td>3s tailgater</td>
<td>20.95%</td>
<td>16.42%</td>
</tr>
<tr>
<td>Wednesday</td>
<td>1s tailgater</td>
<td>33.51%</td>
<td>21.01%</td>
</tr>
<tr>
<td></td>
<td>2s tailgater</td>
<td>22.71%</td>
<td>19.57%</td>
</tr>
<tr>
<td></td>
<td>3s tailgater</td>
<td>15.13%</td>
<td>21.01%</td>
</tr>
<tr>
<td>Thursday</td>
<td>1s tailgater</td>
<td>36.95%</td>
<td>25.33%</td>
</tr>
<tr>
<td></td>
<td>2s tailgater</td>
<td>22.19%</td>
<td>18.38%</td>
</tr>
<tr>
<td></td>
<td>3s tailgater</td>
<td>16.09%</td>
<td>22.12%</td>
</tr>
<tr>
<td>Friday</td>
<td>1s tailgater</td>
<td>32.35%</td>
<td>24.81%</td>
</tr>
<tr>
<td></td>
<td>2s tailgater</td>
<td>25.89%</td>
<td>21.81%</td>
</tr>
<tr>
<td></td>
<td>3s tailgater</td>
<td>21.17%</td>
<td>17.29%</td>
</tr>
</tbody>
</table>

Percentage of vehicles who broke 2-second rule

<table>
<thead>
<tr>
<th>Day of Week</th>
<th>Percentage of vehicles who broke 2-second rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>62.96%</td>
</tr>
<tr>
<td>Tuesday</td>
<td>59.54%</td>
</tr>
<tr>
<td>Wednesday</td>
<td>56.22%</td>
</tr>
<tr>
<td>Thursday</td>
<td>59.14%</td>
</tr>
<tr>
<td>Friday</td>
<td>58.24%</td>
</tr>
</tbody>
</table>

Percentage of vehicles who broke 3-second rule

<table>
<thead>
<tr>
<th>Day of Week</th>
<th>Percentage of vehicles who broke 3-second rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>76.72%</td>
</tr>
<tr>
<td>Tuesday</td>
<td>80.49%</td>
</tr>
<tr>
<td>Wednesday</td>
<td>71.35%</td>
</tr>
<tr>
<td>Thursday</td>
<td>75.23%</td>
</tr>
<tr>
<td>Friday</td>
<td>79.41%</td>
</tr>
</tbody>
</table>

42
The percentages of three types of tailgaters were fairly consistent regardless of the day of week during both rush hours and non-rush hours (see Figure 5.2 Day of week comparison: I95 1-second tailgater (top), 2-second tailgater (middle), and 3-second tailgater (bottom)).
Figure 5.2 Day of week comparison: I95 1-second tailgater (top), 2-second tailgater (middle), and 3-second tailgater (bottom)

To further assess tailgating issue, the results above were broke down into lanes.

Table 5.2 **Vehicle headway analysis with lane break-downs** shows the results with lane break-down. It shows that tailgating issue (especially the percentage of 1-second tailgater) was worse on the leftmost lane. This might because tailgating was a speed related issue and the leftmost lane usually had the highest speed.

<table>
<thead>
<tr>
<th>Highway sections</th>
<th>Lanes (from left)</th>
<th>1st lane</th>
<th>2nd lane</th>
<th>3rd lane</th>
<th>4th lane</th>
</tr>
</thead>
<tbody>
<tr>
<td>I-95 @ Detroit Ave</td>
<td>1-sec</td>
<td>36.11% 24.68%</td>
<td>47.10% 15.60%</td>
<td>29.92% 21.43%</td>
<td>33.05% 20.95%</td>
</tr>
<tr>
<td></td>
<td>2-sec</td>
<td>22.22% 16.88%</td>
<td>18.06% 28.44%</td>
<td>24.41% 21.23%</td>
<td>24.58% 23.81%</td>
</tr>
<tr>
<td></td>
<td>3-sec</td>
<td>14.59% 18.18%</td>
<td>17.42% 20.18%</td>
<td>18.11% 23.43%</td>
<td>16.10% 12.38%</td>
</tr>
<tr>
<td>I-195 @ Rte. 114</td>
<td>1-sec</td>
<td>23.53% 19.64%</td>
<td>11.54% 19.67%</td>
<td>20.69% 13.98%</td>
<td>18.26% 16.31%</td>
</tr>
<tr>
<td></td>
<td>2-sec</td>
<td>12.76% 7.15%</td>
<td>23.08% 13.12%</td>
<td>37.93% 21.50%</td>
<td>23.35% 25.93%</td>
</tr>
<tr>
<td></td>
<td>3-sec</td>
<td>12.53% 12.50%</td>
<td>20.07% 19.77%</td>
<td>20.69% 21.51%</td>
<td>16.43% 12.19%</td>
</tr>
<tr>
<td>I-295 N @ Ex. 6</td>
<td>1-sec</td>
<td>34.21% 19.23%</td>
<td>23.08% 11.76%</td>
<td>15.42% 10.24%</td>
<td>17.67% 26.43%</td>
</tr>
<tr>
<td></td>
<td>2-sec</td>
<td>33.22% 26.92%</td>
<td>30.77% 23.53%</td>
<td>13.15% 5.68%</td>
<td>16.46% 12.11%</td>
</tr>
<tr>
<td></td>
<td>3-sec</td>
<td>19.31% 24.56%</td>
<td>15.38% 11.77%</td>
<td>6.14%  6.45%</td>
<td>20.43%  7.20%</td>
</tr>
</tbody>
</table>

These results provided strong evidence that tailgating existed on major highways in Rhode Island despite the time of day effect. This posed serious transportation safety concerns on highway driving, therefore, to conduct a vehicle headway project and to recommend feasible vehicle headway treatments was important to Rhode Island.

### 5.2 Questionnaire survey

All the subjects’ responses were recorded in text files (see Figure 4.26 **Subjects’ answers stored as text files**) and then put in Excel worksheets for analysis.
To help identify major causes of crashes, the participated driver subjects were asked to select the top three (see Figure 4.3 **Major causes of crashes**). According to the weighted scores (a cause got 3 points for being ranked the first once, 2 points for second, etc.), the top three leading causes of crashes are: distraction, speeding, and tailgating (see Figure 5.3 **Pareto chart of major causes of crashes**). Distraction and speeding received much more scores than any other causes. Road rage and DUI also received scores close to that of tailgating.

![Figure 5.3 Pareto chart of major causes of crashes](image)

147 out of 210 subjects said that they did not intentionally follow other cars. Only 29 subjects said it was easier to maintain speed and 31 subjects did so to avoid speeding tickets.

142 out of 210 subjects said that they did not follow other cars closely. Other subjects said it happened sometimes.
104 out of 210 subjects said that it’s safer not following other cars closely, 44 thought following closely was against the law. 36 subjects’ reason of not following closely was obstruction in view, and the rest 26 subjects’ reason was others were driving slowly.

When they were asked about the definition best described tailgating, 160 subjects chose “following too close to the vehicle ahead”, and only 24 chose “insufficient following distance”. This indicated that most drivers had only a qualitative idea of what tailgating means instead of a quantitative one.

“Heavy traffic”, “slow car ahead of my vehicle”, and “in a hurry” were the top 3 choices selected by subjects when asked to choose all applicable causes of tailgating (see Figure 5.4 Causes of tailgating).

![Figure 5.4 Causes of tailgating](image)

When they were asked about their reactions when being tailgated, the answers to this multiple choices question (see Figure 5.5 Drvier’s reactions when being
showed that most of subjects were affected by tailgaters, because only 74 subjects’ answers included “Ignore the tailgater”. Most of them reacted passively that 161 subjects chose “change lanes to let the tailgater pass”.

![Figure 5.5 Driver’s reactions when being tailgated](image)

In the next few questions, 162 out of 210 subjects indicated that they knew what the proper vehicle headway was, 155 out of 210 subjects said keeping a safe vehicle headway was very important, and 190 out of 210 stated that they kept a safe vehicle headway at least most of the time. Those answers gave a positive impression that tailgating was not serious issue in Rhode Island.

However, the answers to the next question indicated that the majority of drivers who took the survey did not know what the proper vehicle headway was, and drove with a dangerous vehicle headway. When driving at 60 mph, a 2-second vehicle headway produces a following distance of 11 car lengths (assuming with a car length
of 15 feet). When question came to “how much distance do you maintain when driving 60 mph on highways”, 95% of subjects said they maintained a vehicle headway less than 11 car lengths, and almost half of total answers were less than 4 car lengths (see Figure 5.6 Vehicle headways maintained by drivers when driving at 60 mph).

Although 158 out of 210 subjects said they maintained a vehicle headway equal or large than 3 seconds, subjects’ opinion on vehicle headway measured in car lengths could be considered more accurate since 165 out of 210 subjects also said they preferred car lengths to measure vehicle headway.

This finding in computer based questionnaire survey, in some way, agreed with the tailgating issue identified in vehicle headway analysis.

![Figure 5.6 Vehicle headways maintained by drivers when driving at 60 mph](image)
134 out of 210 subjects preferred a combination in vehicle headway treatment with both advisory message signs and reference markings.

When various treatment designs were presented, equal-distanced horizontal bars were preferred over other cases (see Figure 5.7 *Drivers’ preference on reference markings*). Graphic-aided dynamic message signs and fixed road signs were both preferred over text-only ones by the majority (88.6% and 80% respectively). The survey also indicated that 53.8% of the subjects preferred overhead dynamic message signs over fixed road signs (27.6%) and roadside variable message signs (18.6%).

![Figure 5.7 Drivers’ preference on reference markings](image)

6. CONCLUSION AND FUTURE WORK
A vehicle headway analysis and a computer based questionnaire survey were employed to examine the tailgating behavior on Rhode Island highways and to find possible means for tailgating treatments.

In the vehicle headway analysis, vehicle headways on specific segments of major highways in Rhode Island were examined through traffic surveillance video provided by the Rhode Island Department of Transportation. Tailgating behaviors on major Rhode Island highways, during rush hour and non-rush hour between Monday and Friday, were compared.

Although, comparing to rush hours’ results, significant reductions in all tailgater percentages were observed at all three locations during non-rush hours, there were still about half of the vehicles were with less than 3 seconds of headways, about 30% to 40% vehicles were with less than 2 seconds of headways, and around 20% vehicles maintaining less than 1 second of headways. Moreover, these percentages were consistent regardless day of week for during both rush hours and non-rush hours.

Tailgater percentages with lane break-downs showed that vehicle headway issue (especially the percentage of 1-second tailgater) was worse on the leftmost lane.

The vehicle headway analysis confirmed the presence of vehicle headway issue on major highways in Rhode Island despite time of day and posed serious transportation safety concerns on highway driving. Therefore, it is important for Rhode Island to conduct a vehicle headway study and to find a suitable vehicle headway treatment.

A questionnaire survey was designed to identify the causes of tailgating and to gain insights about drivers’ preferences of various design features of tailgating
treatment. A total of 210 driver subjects participated in the survey and provide valid responses.

The findings of the survey indicated that the majority considered “tailgating” a serious offense as it was ranked top three major causes of crashes. Most of them, however, only had a qualitative idea of what tailgating means instead of a quantitative one, i.e., did not understand what the proper vehicle headway was when driving on highways and maintained dangerous vehicle headways while driving. This finding, in some way, agreed with the tailgating issue identified in vehicle headway analysis.

Among a few tailgating treatments, subjects preferred the one with equal-distanced horizontal bars painted on highway pavement as reference markings and graphic-aided dynamic message signs as advisory message signs. This would be the tailgating treatment system recommended to Rhode Island at current stage.

As discussed above, the vehicle headway analysis and the computer based questionnaire survey exhibited somewhat similar findings and agreed on serious tailgating issue on Rhode Island highways. The survey also indicated that drivers preferred tailgating treatment system with equal-distanced horizontal bars painted on highway pavement as reference markings and graphic-aided dynamic message signs as advisory message signs which could be implemented on Rhode Island highways.

Future works regarding this study might include further vehicle headway analysis. Although vehicle headway analysis in this study confirmed the existence of the tailgating phenomenon, sampling two-week’s of traffic surveillance videos in December only could not be considered convincing. More traffic videos recorded
from longer period are needed to reach a conclusive statement of tailgating issue in Rhode Island. Instead of showing static vehicle headway treatment designs to driver subjects, more accurate results could come from drivers’ responses to dynamic scenarios with built-in treatments. Therefore, future works also include validating some of the survey results by conducting driving simulation experiments with driving simulator. Furthermore, recommended vehicle headway treatment systems validated by driving simulation need to be assessed via field test before implemented on Rhode Island highways.
LIST OF REFERENCES


