Statistical Analyses of the Perceptions and Trust of Adaptive Cruise Control Owners

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Abstract

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Adaptive Cruise Control (ACC), an advanced version of conventional cruise control (CCC), can detect the distance to a vehicle ahead and assist drivers in maintaining a set speed and headway distance. The system has been available in the US since 2001, and there are approximately 70 vehicle models with ACC as standard or optional feature on the road. This study examined the characteristics of drivers that own ACC including their perceptions toward the system, and willingness to trust the system to take control in various situations. Survey data on ACC preferences from Washington State were used to examine both issues. A binary logistic model was used to examine the likelihood that a driver would own a vehicle with ACC. The findings showed that younger (< 45 years old) drivers were more likely to be ACC owners. Further, the type of vehicle that respondents stated they own also influenced ACC ownership. More specifically, Toyota or Lexus owners were more likely to be ACC owners when compared to other vehicle brands. The findings also suggested that those who selected their vehicle because it was perceived to be safe were less likely to own a vehicle with ACC. ACC owners reported higher levels of trust in ACC but this finding might be biased given their existing experience with the system. An ordered logistic model with only ACC owners was then conducted to explore the issue of trust further. Higher trust was associated with drivers' perceptions of ACC (safety and convenient issues) and driver behavior (ACC usage). An exploratory word cloud analysis was conducted to obtain additional insights on drivers' safety concerns with the system. Of the 34 that responded, safety concerns related to ACC's braking capability and gap settings were raised, which can be explored in future studies.

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INTRODUCTION

There are many in-vehicle technologies integrated in the modern day car. However, the use of these technologies, or perception of use, may be influenced by factors that do not always lead to safe vehicle operation. Advanced Driver Assistance Systems (ADAS) are designed with the goal of enhancing traffic flow and driver safety, and are becoming a more integral part of the vehicles on the road today. However, there are still concerns related to their safety and reliability. One example of ADAS is Adaptive Cruise Control (ACC), which has been shown to have a marginal improvement on highway capacity (VanderWerf, Shladover, Miller, & Kourjanskaia, 2002), and a large impact on traffic flow, especially during peak hours (Klunder, Li, & Minderhoud, 2009). However, its impacts on safety is still unknown (Rudin-Brown & Parker, 2004). A key factor related to safety is drivers' interaction with ACC and more specifically, driver's trust, reliance, and misuse of the system. These human factor issues are examined in this study using surveys on driver's self-reported perceptions of ACC.

There have been a few studies conducted on ACC using surveys: Jenness (2008) conducted a survey in South California for the primary purpose of understanding ACC use among different ages; Llaneras (2006) conducted a survey on acceptance and adaptation to ADAS, which also included the ACC system. Dickie & Boyle (2009) and Bato (2011) conducted similar surveys in Iowa and Washington State, respectively, to understand drivers' perceptions, acceptance and actual usage of the technology. This thesis uses the survey described in Bato (2011) as the framework for examining factors related to ACC ownership including demographic information (e.g., age, gender), reported ACC system use, perceptions of ACC, and knowledge of ACC.

The overall goal of this current study was to understand whether Adaptive Cruise Control (ACC) can help or hinder overall driver safety, given the limitations and capabilities of the in-vehicle technology. It is possible that ACC systems could also help drivers in other ways including enhance comfort and reduced workload. But it is also possible that the system can be misused and misunderstood by drivers. This current study uses survey data to assess the likelihood of a driver owning an ACC. If a driver does own an ACC, how much trust does the driver place in ACC to function properly under various road and environmental conditions. It is hypothesized that perceptions of safety and acceptance (either positive or negative) will have an impact on ACC owners' trust in the system.

The thesis format is divided into four sections. Chapter 1 provides the background of ACC systems, surveys, and discusses the related human factor issues in ACC use. Chapter 2 presents the background on survey design and statistics modeling methods used in this analysis, as well as data source and the analysis. Chapter 3 shows the results of the analyses. The thesis concludes and further discusses in Chapter 4, the research results and the implications of the findings.

CHAPTER 1 BACKGROUND

Advanced Driver Assistance Systems (ADAS) are in-vehicle systems designed to help motorists while they are on the road. The purposes of these systems are to enhance drivers' safety, comfort, convenience, travel time, or a combination thereof (Blythe & Curtis, 2004). These in-vehicle technologies can supplement drivers' limited sensory and information processing capabilities, and in doing so, assist them in maneuvering through safety-critical driving situations. Examples of ADAS that are commercially available as a standard or optional feature include forward collision warning systems, enhanced night vision, automatic parking, in-vehicle navigation systems and adaptive cruise control (ACC). This thesis focuses on drivers' ownership of ACC, and their perceptions and trust of the ACC system.

Introduction to ACC

System Definition

ACC is an advanced version of conventional cruise control (CCC) system that can also help detect the distance to the vehicle ahead and provide assistance by keeping the vehicle at a set speed and distance away from the vehicle directly ahead. One key part of an ACC system is the range sensor, which includes a radar, Lidar, or video camera. These sensors measure both the distance and the relative velocity of the two successive vehicles (Figure 1), and would inform the Electronic Control Unit (ECU) when a preceding vehicle is detected (Winner, Witte, Uhler, & Lichtenberg, 1996). The ACC control module then calculates whether to brake or stay at the user-set velocity (Xiao & Gao, 2010).

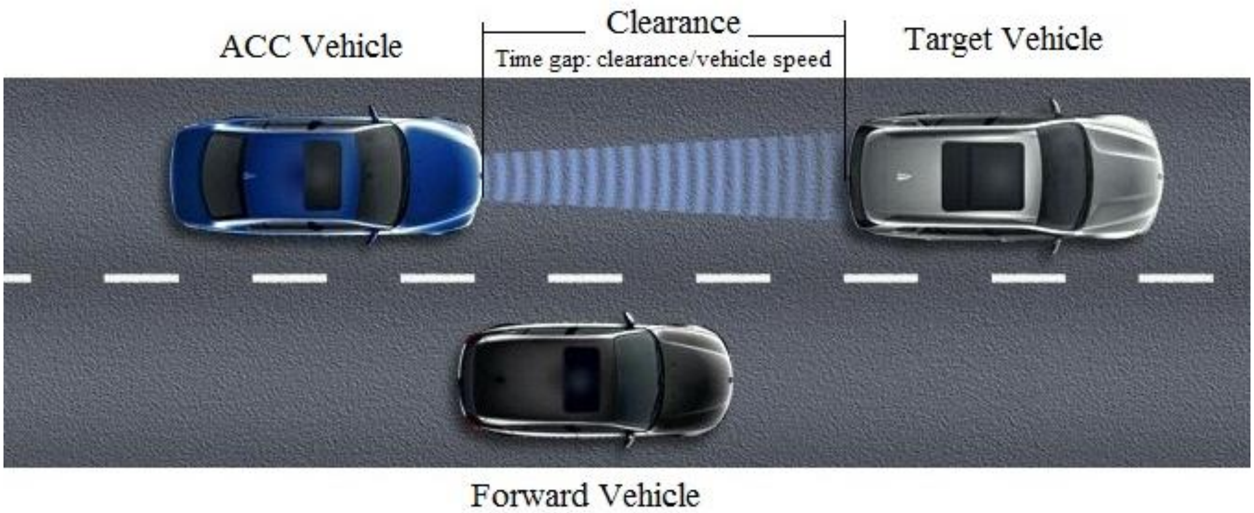


Figure 1 Overview of ACC operation
Revised from ("Adaptive Cruise Control System Overview," 2005; BMW)

Development of ACC

ACC systems were first introduced in luxury vehicles (e.g., BMW, Mercedes, etc), but have transitioned to intermediate-priced vehicles such as Toyota Sienna and Volkswagen Passat (Xiao & Gao, 2010). Although ACC systems are becoming more common in automobiles, it is still important to understand how ACC has evolved over time.

The history of ACC can be traced back to the 1960s. The idea was raised by Diamond and Lawrence in 1966 and was initially conceptualized as an automatically controlled highway system (ACHS) (Diamond & Lawrence, 1966). Around the same time, Levine and Athans (1996) came up with a design for an optimal linear feedback system to adjust the speed and positions of each car in a string of moving vehicles.

The research and concepts related to ACC stayed within the academic community until 1986 when it was finally considered in industry. This timeframe coincided with the rapid development of automobiles and the issues surrounding increase automobile ownership:

congestion, crashes, and driver stress; problems now being addressed by the public sector and policy makers (Catling, 1993; Loannou, 1997). The implementation of ACC seemed to be one way to address some of these motorist concerns (Catling, 1993; Ioannou, 1997).

Automobile manufacturers, suppliers of electronics, and research institutions began working together to examine solutions and standardization of ACC. In Europe circa 1991, nine tested vehicles were demonstrated to be useful and robust in sensing angle and range (Catling, 1993).

The ACC system became commercially available in 1995 as part of the Japanese market in the Mitsubishi Diamante (Gee, 1997). The European automobile market included ACC in their vehicles beginning 1998, while North America started including ACC in production vehicles around 2000 (Bishop, 2005). In the US, ACC became standard equipment in only a small number of models. These included the Cadillac XLR, the Mercedes-Benz SLR, Jaguar's XJ-Series (Super V8 and XJR) and Toyota's Sienna (XLE Limited) (Jenness, et al., 2008).

Similar to the conventional cruise control (CCC) system, the initial ACC system could maintain user-defined speed as well as downshift in response to a slowing lead vehicle (Gee, 1997). Currently, ACC allows a driver to set a desired speed, as well as the headway distance (long, medium and short). Usually, ACC works at or above a speed threshold that ranges from 20 to 28 mph. All ACC systems can brake automatically and alert the driver both audibly and visually when detecting that a lead vehicle is too close to the host vehicle.

Most automobile manufactures continue to improve this technology. As an example, BMW has stated that their ACC system can now detect curvy situations (BMW Technology). This advanced system not only is based on ACC sensor, but also combines sensors from other systems, such as ABS, ASC+T, and Dynamic Stability Control (DSC). They could then continually send data on wheel revolutions and levels of vehicle pitch and centrifugal force to the central on-board computer. With this and the car's current path from the navigation system, the system is able to calculate whether the cruise speed should be adjusted, to determine whether vehicles in the radar's field are in the same or a neighbor lane, and in addition, can calculate the approaching curve path (US Autoparts).

Since 2007, the BMW 5, 6 and 7 series have been equipped with the improved ACC with the Stop &Go feature as options. There are three radar sensors with a range of 150 meters ahead. If the lead vehicle stops, ACC with Stop &Go would bring the host BMW to a complete standstill. It would start the host vehicle again if the vehicle ahead moves off or changes lanes and the total standstill is still shorter than three seconds. The system can also give acoustic and optical warnings if it detects safety critical situations (BMW Technology).

Currently, long range radar (LRR) sensors and the light detection and ranging (Lidar) sensors are more commonly used in ACC equipped vehicles. In order to improve this system, mid- and short-range radar as well as video cameras could be applied in the new generation (Abou-Jaoude, 2003; Jurgen, 2006).

There are more advanced ACC systems (e.g., ACC with curve detective feature and Stop & Go ACC) but they are not common. These improved systems are only available in a small portion of the luxury vehicle market. In this thesis, the ACC systems examined refer to the most commonly used Adaptive Cruise Control systems, described in the next section.

Operation of ACC

A common design of the ACC interface is an information display on the dashboard that provides feedback to the driver on the ACC operation (Figure 2 is an example from the (BMW; Gearlog, 2009)). To date, most ACC systems allow users to set the desired speed and change the following distance, and will show this information on the dashboard. In most cases, following distance is set, by default, as the longest distance setting (for example, in the Toyota Sienna or Avalon). Some systems also depict the distance as time (e.g., a 1 or 2 second gap), while others depict it as distances (e.g., near, medium and far) (Bato, 2011).

Figure 2 Displays of ACC engaged for velocity and distance control in BMW 3 Series (BMW; Gearlog, 2009)

Figure 3 (US Autoparts; Xiao & Gao, 2010) shows an example of the ACC system's architecture. Information from the outside environment and driver are analyzed within the system. The driver needs to first engage ACC by setting the speed and headway. The system then begins to operate, while maintaining the vehicle at a set velocity as well as detecting preceding obstacles. ACC requires sensors to detect the speed and headway distance, as well as the driver's depression of the gas and brake pedals. This data is then sent to a central control unit, also known as the Distance/Speed (ACC) Control module (Xiao & Gao, 2010). The set speed and headway are displayed on the dashboard of the vehicle. This information is also analyzed by the Distance/Speed (ACC) Control module. If no object shows up in front of the automobile, or if the lead vehicle is further than the set headway, the control module would then control the engine to achieve the set velocity. If the host vehicle approaches the lead vehicle too quickly given the desired headway distance, the control module would automatically slow down the host vehicle.

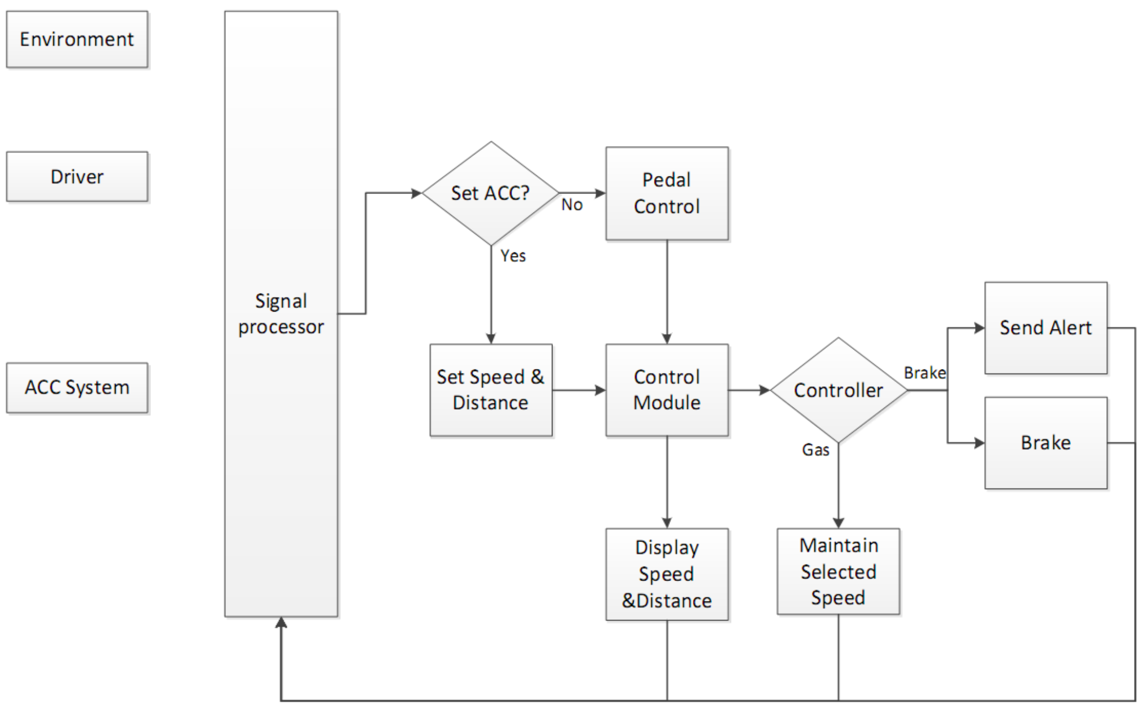


Figure 3 Adaptive Cruise Control system architecture (US Autoparts; Xiao & Gao, 2010)

Assistive systems, such as ACC, require a balance between the operator, system, and the environment (Bato, 2011), and are set up as a closed loop system. Any actions initiated by the automobile and/or the driver would be sent back to the system module to ensure that a real-time analysis can be conducted for timely feedback. The real time feedback ensures that the driver is provided information on the current driving environment. The driver and the system therefore, work in cooperation so that information flows easily between them.

Although all ACC brands share the same idea and working principles, there are differences with regard to settings, displays, and controls. There are two primary range sensors manufactured for ACC: one is from Bosch and the other by Denso. Table 1 shows the differences based on two car manufacturers, BMW and Toyota. The ACC system integrated into the Lexus brand is identical to Toyota (since Toyota is the parent company of Lexus). Hence, they are grouped together in the table.

Table 1 Comparisons between two main kinds of ACC detective systems

	BMW	Toyota (and Lexus)
Radar Brand	Bosch	Denso
Radar	A sensor that has a fixed antenna with Frequency Modulated Continuous Wave (FMCW) output	A more conventional type of radar: mechanically sweep back and forth antennas
Distance calculated by	Compare the frequencies of the transmitted signal and its echo Distance is set as a number of seconds, not of meters	Measure the time between transmission and reception
Relative speed detected by	Compares the frequency shift of the transmitted signal and its echo	The frequency shift (Doppler Effect) of the reflected waves
Angular position	A 77 GHz three-beam overlapping radar sensor	The phase differences of the signals received by multiple antennas: separate receiving and transmitting antennas (2 cameras)
Headway setting	Four levels	Three levels
Minimum speed	20 miles/h	25 miles/h
Radar detection length	120m	NA
Radar detection angle	NA	World’s widest detection angle
Adaptability to curve path	Was able to calculate the approaching curve path	NA
Adaptability in bad weather	Built-in heaters in the radar sensor apparatus	Enabled when windshield wipers are in use
Deceleration	2 m/sec^2	2.94 m/s^2 (0.3 g)
Auditory and visual alert	Yes	Yes

Human Factors Issues Related to ACC Use

ACC is typically available in higher-end vehicles (Llaneras, 2006) and marketed as a convenience system, rather than a safety system (Kesting, Treiber, Schonhof, & Helbing, 2007; Klunder, et al., 2009; Rudin-Brown & Parker, 2004). The ACC system does have limitations (VanderWerf, et al., 2002) and based on today's technology, is not designed to replace the driver. Even though ACC was introduced over ten years ago and gaining in use, there still exists a subpopulation of drivers that do not understand how it should be appropriately used (Hoc, Young, & Blosseville, 2009; Jenness, et al., 2008; Xiao & Gao, 2010). Therefore, it is important to examine whether users understand how ACC functions so it can be used properly.

Limitations of ACC

ACC systems have the potential to reduce crashes (Young, Stanton, & Harris, 2007) because it can provide drivers information on the status of the vehicle and even respond to some potential hazards (Hoc, et al., 2009). However, it is still a semi-automated system (a shared control system) and drivers' cooperation control (usage) plays an important role in driver safety. Further, since ACC system is really designed for convenience (Kesting, et al., 2007; Klunder, et al., 2009; Rudin-Brown & Parker, 2004; Stanton & Young, 2005), the limitations associated with ACC can have an impact on overall safety. Though such limitations are acknowledged by manufacturers and researchers (Bato, 2011; Dickie & Boyle, 2009; Jenness, et al., 2008; Rajaonah, Anceaux, & Vienne, 2006a; Rajaonah, Anceaux, & Vienne, 2006b; Rudin-Brown & Parker, 2004), many current ACC users are still not aware of these limitations and many use the system inappropriately.

Interestingly, the car owner's manual typically lists warnings and limitations about ACC. However, as noted by Jenness (2008), as many as 72% of ACC owners are still unaware of any manufacturers' warnings or limitations about their ACC systems. The system is not capable of bringing a vehicle to a complete stop. Almost all ACC systems today have a braking feature that may not work as well when the vehicle ahead brakes too abruptly (Bato, 2011; Dickie & Boyle, 2009; Rudin-Brown & Parker, 2004). Most ACC systems cannot achieve deceleration rates greater than 0.3g, which is needed to make a vehicle come to a complete stop. More importantly, drivers may actually have longer reaction time (Rudin-Brown & Parker, 2004) in such situations, which can then result in a rear-end crash.

Drivers often perform in a cooperative manner with normal traffic. That is, drivers will typically slow down or change lanes when they detect another vehicle attempting to merge into their lane. However, a normal ACC system is not as intelligent and it only detects vehicles directly in front of the host vehicle but not vehicles around it that may be potentially merging (Pauwelussen & Minderhoud, 2008). The ACC system may also not operate properly when a vehicle cuts into the lane of the ACC vehicle or if the ACC vehicle is following a vehicle around a sharp curve (Rudin-Brown & Parker, 2004).

In addition, the system may not function properly at low speeds (Rajaonah, et al., 2006a), or in certain rain and snowy conditions (Bato, 2011; Dickie & Boyle, 2009). The sensors may actually detect rain and snow as obstacles and slow down the vehicle improperly. Other noted limitations include unexpected or uncomfortable acceleration or deceleration and incorrect sensor detecting (Jenness, et al., 2008).

Usage/Usability of ACC

Usability relates to many things that include the efficiency and satisfaction of use. It can also encompass perceptions and feelings of confidence. It reflects the general habits and behaviors associated with system use and are related to users' willingness to use the system. Some studies show that in-vehicle assistive systems can decrease operator workload (Rottger, Bali, & Manzey, 2009) and provide opportunities for drivers to focus on the primary goal of driving. Llaneras (2006) showed that there was a 29% increase in ACC usage from the initial purchase date indicating that familiarity with the system may increase usage in the system. Compared to using conventional cruise control, almost half of the respondents in Llaneras' study indicated that they used ACC systems more frequently after they were first introduced to the feature.

There are many studies on ACC related to usage. For example, Viti et al. (2008) showed that ACC could only be engaged during free-flowing driving conditions and low to moderate density situations, but that the system was more likely to be overruled by drivers in busy traffic and congestion. In simulated driving tests, ACC has been shown to reduce situation awareness, workload and stress (Stanton & Young, 2005). Pauwelussen and Minderhoud (2008) found that drivers were more likely to override ACC control when overtaking a lead vehicle. Rajaonah (2006a) showed that ACC users tend to deactivate ACC more by braking rather than with the disengage switch. According to Bato and Boyle (2011), most drivers perceived ACC to be quite helpful with half indicating that changed lanes less frequently with ACC engaged.

Speed and time headway are two important characteristics related to ACC usage. Some scholars (Tricot, Rajaonah, Pacaux, & Popieul, 2004) reported that ACC could result in a more homogenized mean speed. The mean velocity and standard deviation of speed were shown to decrease in the majority of drivers that were examined using ACC. With respect to headway, Jenness et al. (2008) reported that half of the survey respondents readily adjust the gap between the vehicle and the vehicle ahead depending on traffic conditions. In situations where a truck suddenly cut in front of the host vehicle, the time headway (in seconds) was much shorter when the driver allowed ACC to slow down than when the driver controlled the vehicle manually (Rajaonah, et al., 2006b). People who often overtook usually found ACC's slowing down feature annoying because it slowed down automatically when passing the lead vehicle. These same individuals were also observed to use ACC only moderately (Tricot, et al., 2004). Still, ACC has been shown to be useful in reducing the likelihood of a crash between the vehicle equipped with ACC and the lead vehicle, while at the same time slightly increasing crash risk for the followers of the host vehicle (Touran, Brackstone, & McDonald, 1999).

Perceptions of ACC

Near autonomous machines are likely to interfere with human activities (Hoc et al, 2009). Such interference can raise other issues such as over-trust in and over-reliance on a system, and longer reaction time. There are two kinds of perceptions toward vehicle technology: those who feel that technology can help achieve a better and safer traffic system, and those who feel that technology can have a potentially negative impact on driver behavior and actually negate any safety benefits that could be gained by the technology (Marell & Westin, 1999). Therefore, it is important to examine drivers' adaptive ability, how driving behavior would be impacted by ACC, and whether drivers base their trust and reliance on correct understanding and perceptions of ACC.

When provided a description of ACC, people tend to trust the technology (Rajaonah, et al., 2006a). After actual usage of ACC in a simulator, drivers' trust in ACC on all aspects appear to increase, but the level of trust did not appear to get higher with extended use (Rajaonah, et al., 2006a). In the simulator study by Rudin-Brown et al (2004), drivers also showed greater trust in ACC and that trust remained high even if the ACC system failed. Subsequently, some drivers may actually fail to take back control if ACC is not working properly (Stanton, Young, & McCaulder, 1997). Several simulator experiments also showed that returning to manual control after ACC usage was a problem for ACC users because they already relied on ACC and have adapted to using it (Hoc, et al., 2009; Young, 2002).

After actual ACC use, drivers tended to regard ACC as a safety feature and felt ACC helped to decrease their crash risk when compared to CCC (Llaneras, 2006). Most participants (54%) in Jenness's (2008) study reported that they did not feel more or less safe using ACC. More than one third of them thought they were safer because of ACC while only 7 percent reported the opposite. In general, drivers appeared to be overconfident in their abilities with ACC as demonstrated by Llaneras et al. (2006) and Jenness et al. (2008). In their studies, ACC owners indicated that they were able to respond similarly and maintain the same or greater headways whether ACC was engaged or not.

Surveys to Examine ACC Behavior

Examining drivers' opinions and perceptions of technology can be difficult. In some respect, examining the efficient use of the technology (which has been extensively examined) is more easily quantifiable (Nielsen & Levy, 1994). Surveys can be used to gather changes in driver behavior due to real-world system experiences (behavior adaptation), as well as driver acceptance based on ease-of-use, effectiveness, and desirability (Llaneras, 2006). Rajaonah, et al. (2006a) also used questionnaires to associate drivers' trust with their beliefs and other evaluations. Other survey studies on acceptance and perceptions of technology in the driving domain include the examination of variable speed limits (Khoo & Ong, 2011), drivers' perception of trucks cutting-in (Rajaonah, et al., 2006b), and also on ACC use (Hoedemaeker, 2000; Jenness, et al., 2008).

This thesis used the survey designed and distributed by Bato (2011), who administered two sets of surveys in Washington State: Phase 1 and 2 with the conclusions drawn from Phase 1 presented in Bato's thesis. This current thesis examines the survey administered in Phase 2. The targeted population was ACC owners, but the sampled population was potential ACC owners. Since ACC is still not widely available in all US makes and models, researchers can still pull out potential owners using the vehicle identification numbers (VINs). However, the VIN cannot identify whether the vehicle actually had ACC as an option or whether the driver actually used this feature. That stated, the vehicle owners who did not have the ACC feature but still received a survey were highly encouraged to complete the surveys.

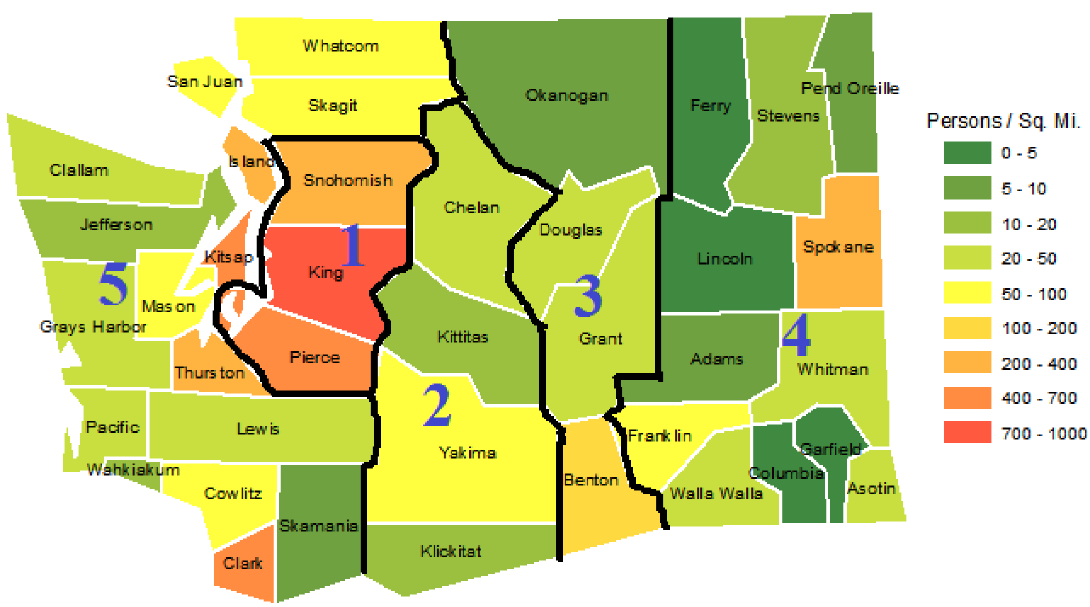
Chapter Summary

In this chapter, a brief introduction of ACC associated with a summary of the literature is presented. At the beginning of this chapter, an overview of how ACC works is given after a brief overview of the development of the ACC system. This literature review is critical to gain a complete picture of how people perceive and use ACC. More specifically, it was found that some ACC owners had limited perceptions about the system, while other drivers were not aware of the limitations of ACC. Afterwards, conducting surveys is appropriate in this study, and the reason will be discussed. There were several researchers who have conducted surveys to access people's perceptions towards ACC. The remaining chapters of this thesis details the statistical models that best determine the profile of automobile owners most likely to be ACC owners, based on their perceptions and trust in ACC.

CHAPTER II METHODS

Survey Design and Distribution (Data)

A summarized version of the survey distributed by Bato (2011) is presented here to provide context for the study population. In order to reduce bias from heavily populated areas and to ensure broad representation across the state, a county-stratified and population-based random sampling technique was used (Figure 4). The sampled population was chosen based on the Vehicle Identification Numbers (VINs), obtained from the Washington State Department of Licensing, for the vehicle make, model and year most likely to be equipped with ACC. It is important to note that even though the VINs indicate potential ACC vehicles, this feature may not be included in the respondent's vehicle. Respondents that did not own ACC were still invited to complete the survey to gather information on driving styles, demographics, and reasons for not selecting ACC.



Figured 4 Population density by county and stratification method (Bato, 2011; Office of Financial Management, 2010)

A basic description of an ACC system was provided at the beginning of the survey so that all respondents would have the same understanding/intent of the system being evaluated. There were 72 questions in total and these questions addressed perceptions towards ACC, ACC use, driving habits, and demographic questions (age, gender, vehicle usage, etc.). There were four additional questions asking participants if they were available for future studies. Respondents were asked questions on their perceptions towards ACC, perceived usefulness in terms of effectiveness, ability to function properly under various road and environmental conditions, and trust in ACC. For ACC owners only, information was gathered on actual use under various road and environmental conditions. The participants were provided a set of multiple choice options for most questions. There were also several opportunities for them to write in comments. The full version of the survey can be found in the appendix.

The survey was designed to be completed within 15 minutes. Each survey participant was compensated with a $10 gift card for their involvement (Bato, 2011). There were 2000 surveys distributed with 128 returned due to invalid addresses. In total, 584 (31.2% response rate) were returned and of these, 20.2% (n=118) reported they were ACC owners. There were several survey questions examined in the subsequent data analysis and these are included in Table 2.

Table 2 List of survey questions

Variable Name	Questions
ACC Ownership	Do you currently own a vehicle with ACC? (binary)
Trust in ACC	Question: "How much do you agree or disagree based on ACC definition: I trust an ACC system would work." (5-point Likert)
Age Group	ACC driver age (integer); Grouped as Younger and Older Group
Make	ACC vehicle make (string); Grouped as Toyota &Lexus, with other makes
Number of people in Vehicle	Indicated the reported average number of people in the driver's vehicle including the driver (number)
Specifications	Question: "I selected this vehicle primarily because: I wanted the basic specifications." (binary)
Style	Question: "I selected this vehicle primarily because: I liked the styling and looks." (binary)
Safe	Question: "I selected this vehicle primarily because: I wanted safety and quality." (binary)
Feel Safe using ACC	Question: "Please state how much you agree or disagree with the following statements: I feel safe using the ACC system." (5-point Likert)
ACC is Convenient	Question: "Please state how much you agree or disagree with the following statements: ACC is convenient to use." (5-point Likert)
Helps on curvy road	Question: "Please rate how much you think that ACC would help you in avoiding a crash with the vehicle in front of you if: you are following the vehicle on a curvy road." (5-point Likert + "Don't know")
Use ACC in free flowing traffic	Question: "Please rate how often you use ACC in the following conditions: in traffic that is flowing." (5-point Likert + "Don't know")
Use GPS with ACC	Question: "Please rate how often you use ACC in the following conditions: when using a GPS receiver or other navigational system." (5-point Likert + "Don't know")
Comments	Does ACC create any new problems or safety concerns for you? (binary) Does ACC create any new problems or safety concerns for you? If "yes", please explain. (string)

Statistical Analysis

Logistic regression models is a technique that was proposed as an alternative to linear regression models in the late 1960s and early 1970s (Cabrera, 1994). This study used two logistic models to examine two outcomes of interest: ACC ownership, and trust in ACC among ACC owners.

Binary Logistic Regression Model

Logistic regression is used to generate odds ratios or the probabilities of the target event occurring based on a combination of explanatory variables. The logits usually defined as the natural logarithm of an odds ratio. Odds ratios represent the probability (π) that one event happened when compared to the probability (1-π) of that same event not happening (Peng, Lee, & Ingersoll, 2002). The logistic function is written as:

$$log\left(\frac{\pi}{1-\pi}\right) = \beta_0 + \beta_1 x_1 + \cdots + \beta_p x_p + \varepsilon \qquad \text{equation (1)}$$

where, π represents the probability of the target event, the β_i represent the coefficient for the explanatory variable x_i. In this case, the dependent variables should be binary, i.e. its value should be either 1 or 0. Independent variables can be continuous or discrete. While the logit function can take any value in the equation, the probability π will always lies between 0 and 1 (Everitt & Hothorn, 2010).

Dependent Variable

The analysis examined the likelihood that a driver owned a vehicle equipped with ACC. Hence, a binary outcome was used to identify those who owned and not owned this system.

Explanatory Variables

Explanatory variables considered for this model (ACC ownership) included: trust in ACC, age, number of people typically in the vehicle, whether they were Toyota or Lexus owners, and reason for selecting current vehicles.

Trust in ACC: The original trust question was: "Please state how much you agree or disagree with the following statement: I trust an ACC system would work". Participants selected their answer from a 5-point Likert scale: (1) strongly agree, (2) agree, (3) neutral, (4) disagree, (5) strongly disagree. The hypothesis for the ACC ownership model was that those who have a higher trust in ACC would be more likely to own ACC. Hence, difference between the two extreme viewpoints (strongly trust, and strong distrust) was of interest and as such, this variable was categorized as a binary variable: Highly trust and others (includes all other opinions beside strongly agree).

Age: Age was separated into two categories: younger (<45 years old) and older (≥45 years old). The survey respondents' encompassed a mean age of 56.34 (sd=14.57 years old) and the age category was based on the first quartile (Q1).

Number of people in vehicle: The number of people usually in the vehicle showed another basic characteristic of ACC owners. This variable can give some insights on owners' household size and why ACC may be useful to different households. This variable was treated as an integer with values ranging from 1 to 6.

Vehicle Brand: A category of vehicle type (Toyota or Lexus vs. other brands) was included since many respondents indicating having this vehicle type (43.3%) and it was of interest to see if these drivers might differ from other brand owners (e.g., BMW, Infiniti, etc. See

Table 10 in Appendix for the frequency of each vehicle type). Also, Toyota and Lexus are made by the same parent company and their ACC systems designs are identical. For these reasons, this group was of interest and included in the model.

Reason for selecting the current vehicle: In general, customers chose automobiles for many reasons. For example, they may prefer the reliability (quality), safety, or another special feature. In this current survey, respondents were asked to select the most important reason for selecting their current vehicles, which includes the seven most common reasons. They were:

- I want safety and quality;
- I liked the styling and looks;
- I wanted the basic specifications;
- I liked the features offered;
- The cost is within my budget;
- I did not choose this vehicle;
- The vehicle has ACC.

The above listed reasons are in the order of highest selection among respondents to lowest. In this current model, the top three reasons were used as the three factors in the model: safety, style and specifications. These factors were selected because they may provide insights on the tradeoffs that drivers consider when selecting a vehicle ACC systems or other characteristics when purchasing a vehicle.

Ordered Logistic Regression Model

Logistic regression model can be used to gain an understanding of drivers' characteristics, perceptions towards ACC, driver behaviors given the likelihood of trusting ACC systems. Trusting ACC has an inherent order that can be modeled using an ordered logistic model. This model is based on the cumulative logit or cumulative probability. The ordered logistic model takes the form:

$$log\left(\frac{p_1}{1-p_1}\right) = \beta_{01} + \beta_1 x_1 + \cdots + \beta_p x_p + \varepsilon \qquad \text{equation (2)}$$

$$log\left(\frac{p_1+p_2}{1-p_1-p_2}\right) = \beta_{02} + \beta_1 x_1 + \cdots + \beta_p x_p + \varepsilon \qquad \text{equation (3)}$$

$$p_1 + p_2 + p_3 = 1 \qquad \text{equation (4)}$$

$$where, p_1 = probability\ of\ not\ trusting\ in\ ACC$$

$$p_2 = probability\ of\ trusting\ in\ ACC$$

$$p_3 = probability\ of\ highly\ trusting\ in\ ACC$$

where, $p_i s$ represent the probability of the target event, the β_is represent the coefficients, and the x_is represent the explanatory variables.

Variables

The purpose of this model was to predict what kind of perceptions and experience will influence drivers' trust in ACC. In this model, only ACC owners were examined to identify whether they were more likely to trust the ACC system they currently own. The original survey question was: "Please state how much you agree or disagree: I trust an ACC system would work". Originally there were five categories: strongly agree, agree, neutral, disagree to strongly disagree. There were an insignificant number of respondents (table 3) requiring a reduction to three categories: not trusting to neutral [coded as 1], moderate trusting [2], and highly trusting[3].

There were less people who hold their opinions neutral (n=8). Only eight respondents who distrust or strongly distrust the system, this compares to participants who strongly trust the system (n=42) or moderately trust (n=45) in the system. Given the sample size, by combining neutral to strongly distrust into one category could make the model better fitted.

Table 3 Number of respondents in each category for trust question

	Please state how much you agree or disagree: I trust an ACC system would work				
No. of respondents	strongly agree	agree	neutral	disagree	strongly disagree
ACC owners	42	45	8	7	1

Actual experience could be divided into mainly two aspects: drivers' perception towards ACC and driver behavior based on actual usage. Explanatory variables for the second model included the effectiveness or perception of ACC and driver behavior.

Perceptions towards ACC: there were three variables in this category, (1) I feel safe using the ACC system; (2) ACC is convenient to use; and (3) The ACC will help me when following the vehicle on a curvy road. These three variables were all treated as binary variables. There were two categories in the "(1) feel safe" variable, as strongly agree and other opinions. In regard to "(2) ACC is convenient" comparisons are between people who agreed with this statement and participants who did not agree. Besides, respondents could be divided into two groups to the question "(3) how much ACC will help when following the vehicle on a curvy road": people who thought it would help much and other opinions. The third variable also could be considered as an environmental factor as studies showed it might influence ACC owners' trust on Adaptive Cruise Control (Bato, 2011; Llaneras, 2006).

Driver behavior: there were two types of driver behaviors included in this model: (1) the frequency of using ACC when traffic is flowing; and (2) the frequency of using ACC when using navigational technology. These variables are used to see if there are any relevant differences in experience based on frequency of use among ACC owners. These two variables were also binary, based on frequency of use (engaged usually/more than half of time versus seldom usage). The full list of variables can be found in Table 9.

Word Analysis

A recent capability given advanced in technology is the ability to tag words and identify the number of times they are used within a manuscript. This ability to tag works has gained popularity in the development of the internet. A growing number of websites show their user services with lists of present tags (e.g., LibraryThing). Word cloud (or tag cloud) can present the input text data visually and can be representative of features, such as frequency of the associated terms, using different font sizes, weight or colors. This format is useful for quickly perceiving the most prominent terms or for locating a term alphabetically to determine its relative prominence (Halvey & Keane, 2007). In this study, word cloud was used to explore one of the open-ended questions in the survey using two web-based word cloud services, as well as researchers' time to interpret the outcomes. The open-ended question of interest was: "Does ACC create any new problems or safety concerns for you? Please explain."

Data Analysis

The first model (ACC ownership) was examined using a binary logistic model and the second model (Trust in ACC) was examined using an ordered logistic model. Both models were developed using the R statistical program (version 2.12.0) with significance assessed at $p < 0.05$.

The binary logistic model predicted the likelihood that a survey respondent was an ACC owner. This was achieved using the glm function with the MASS package. The second model examined trust within ACC owners. Given the rating scale used within the survey, a three category ordered scale was used to depict trust in ACC. This model was developed using the polr function available within the MASS package.

Two web-based word cloud analysis tool were used for word analysis of comments. Among them, Wordler (Feinberg, 2011) was used for examining the outcomes, while the Public Comment Analysis Toolkit (PCAT) (Texifter LLC) was enrolled to reconfirm the results.

Chapter Summary

A survey distributed in the state of Washington was used to examine the likelihood of purchasing a vehicle with ACC. This survey was initially designed by Dickie & Boyle (2009) and revised by Bato (2011). If the survey respondents indicated that they purchased an ACC, the likelihood that they would trust the system is also examined. These two outcomes were of interest because they can provide insights for characteristics of ACC owners, their perceptions and driver behaviors.

CHAPTER III RESULT

Descriptive Statistics

All respondents (ACC and non-ACC owners) were encouraged to answer the survey. There were 390 male respondents (66.8%) and 187 females (32.0%). Some respondents did not include their demographic information (n=7, or 1.2%). The respondents ranged from 23 to 89 years old with a mean age of 56.34 (sd=14.57 years old). The mean number of miles driven was 208 miles per week (sd=187.67) and the mean number of people in the respondent's vehicle was 2 (sd=1.18).

The majority of respondents owned Toyotas (22.8%), Lexus (20.0%), and BMWs (13.2%). Other vehicle makes included Infiniti (8.6%), Cadillac (6.4%), and Mercedes-Benz (6.4%). Unlike the survey conducted in Iowa by Dickie & Boyle (2009), more BMW owners responded in the Phase II surveys in Washington, but a smaller portion indicated also being ACC owners.

Among all the respondents, 62.5% (n=365) purchased their vehicle new and 36.5% (n=213) purchased their vehicle used (the remaining 1% [n=6] did not indicate how they obtained their vehicle). There were 15 (2.6 %) responses that indicated they had ACC but identified a vehicle that was older than 2001. This was not possible because ACC was not available in the US at that time and therefore, the data from these 15 participants were not included in subsequent data analysis.

A brief introduction of the ACC system that was in their vehicle was provided at the beginning of the survey. All participants were asked to rate how much they agree or disagree with certain statements based on their perception of ACC. There were 62.1% (362 out of 583) participants indicating they would use ACC often. Forty-one percent (240 out of 582) thought ACC could reduce stress when driving, and only 10.5% (61 out of 581) thought ACC could allow them to do other things while driving. The majority did not agree that ACC would allow the driver to do other things while driving (79.9%, n=464). Over 50% (299 out of 581) agreed that the ACC system would improve driver comfort, and 26% agreed that ACC could improve traffic flow. A majority of respondents (81.9% of 582 respondents) appreciated technology as a very important part in their life, and 47.5% (277 out of 583) considered the technology in their car was always better.

All participants were asked the question: "[Q4] Would you want ACC if you purchased this same vehicle again?" Those that indicated "yes" included 60.4% of survey respondents (n=353); 14.4% (n=84) responded that they did not want ACC, and 24.7% (n=144) did not know. The remaining three respondents did not answer this question. Of the 118 ACC owners (include the 15 participants who reported that they had ACC before 2001), 76% wanted to have ACC if they purchased the same vehicle again. Only 57% of non-ACC owners wanted to have the ACC feature.

Respondents also provided the reasons why they selected their current vehicles (Figure 5). In general, drivers showed greater emphasis on [A] safety and quality when selecting a car (n=287, 49.1%). The other top two reasons are: [B] I liked the styling and looks (n=120, 20.5%); and [C] I wanted the basic specifications (e.g., seating capacity) (n=84, 14.4%). Less participants chose their vehicle because the [D] features offered (n=62, 10.6%) and [E] the costs (n=14, 2.4%). Relatively few of the current vehicles reported were not the selections by the respondents [F] (n=6, 1.0%). Only 0.9% (n=5) respondents chose the vehicle because it had ACC [G].

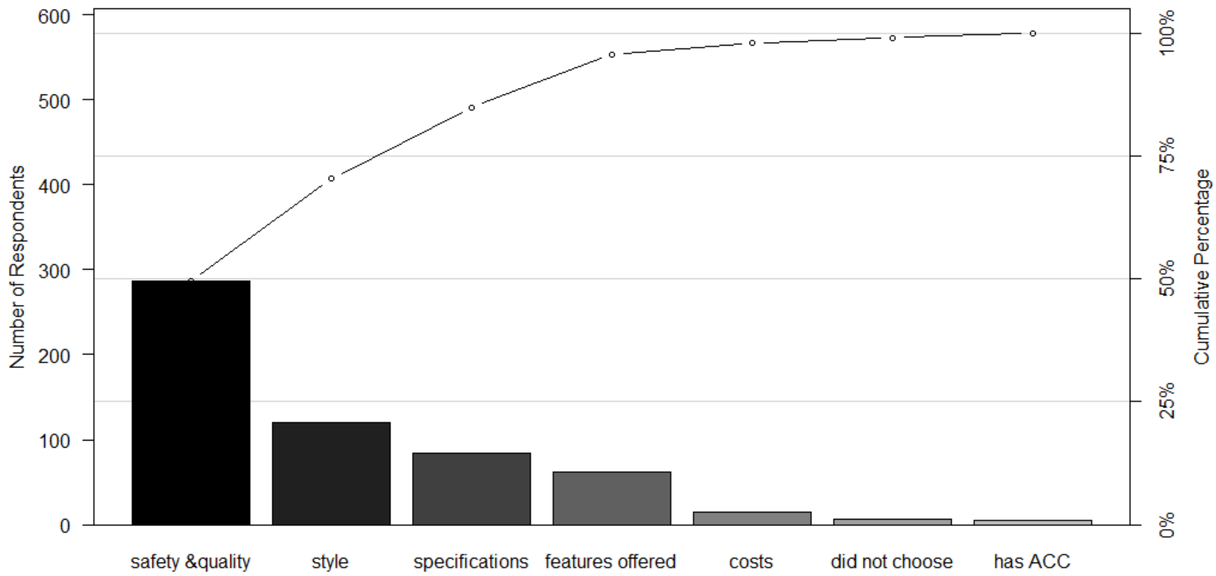


Figure 5 Reasons for drivers to select their vehicle

A total of 15 participants were excluded from further analysis because they indicated they owned a vehicle with ACC older than 2001. The median number of month owned/driving for the remaining ACC owners was 28 months (Range: 2 to 96 months). The majority (n=72, 69.9%) of respondents indicated they would purchase vehicles that have ACC again, and only 4.9% (n=5) of the ACC owners found it difficult to learn how to use ACC. ACC owners on average used ACC or had it engaged approximately 27% of their driving time. Table 4 shows the characteristics of distance setting when ACC was engaged.

Table 4 Property of distance setting

Variable	Category	Count	Percentage
Distance setting	Shortest	20	19.4%
	Medium	38	36.9%
	Longest	25	24.3%
	Other	20	19.4%
The length of following distance when using ACC, compared to not using ACC	Smaller	3	3.2%
	Slightly smaller	5	5.4%
	The same	44	47.3%
	Slightly larger	29	31.2%
	Larger	12	12.9%

ACC was most likely to be engaged on interstates, U.S. highways and when traffic is flowing. There were 60.2% (n=62), 45.6% (n=47) and 43.7% (n=45) of the ACC owners, respectively, who usually or always use ACC on the listed situations above. Although tired or impaired, few (n=14, 13.6%) ACC owners would turn ACC on frequently to help them better driving. Most ACC owners (n=96, 93.2%) seldom or never use ACC on city streets with traffic lights. Besides, 73.8% (n=76) of them were not willing to engage ACC on roads with lower speed limits.

There were two types of questions asked regarding ACC use. One was based on their perception of ACC given a generic description of the system. The other set of questions related to their actual engagement in non-driving activities while ACC was on. It was interesting to compare these two questions because there were very different outcomes between perceptions and actions.

Table 5 Drivers' perceptions and actual usage of ACC when doing non-driving tasks

Perception based on description of ACC Use more often with ACC engaged				In actual driving ACC engaged		
Variable	Category	Count	Percentage	Category	Count	Percentage
Use radio or other accessories	Agree	12	11.9%	At least 50% of the time	40	39.6%
Talk on phone	Agree	11	11%	At least 50% of the time	33	32.7%
Use paper map	Agree	1	1%	At least 50% of the time	11	11%
Use GPS	Agree	17	17%	At least 50% of the time	31	30.7%
Eating or drinking	Agree	5	5%	At least 50% of the time	22	21.8%

From Table 5, it is noted that only a few individuals thought ACC could help a lot when using paper map (1 out of 100), eating and drinking (5 out of 100) compared to the situation that ACC was not engaged. A majority of respondents said they would not use radios, talk on the phone and use GPS more when ACC was engaged. On the other hand, compared to their perceptions, in reality more ACC owners tended to use ACC frequently when using paper maps and eating with proportion of 9% (9 out of 100) and 10.9% (11 out of 101), respectively.

Table 6 shows respondents perceptions of ACC under various conditions. The majority of respondents (61.4%) did not detect a change in responding to hazards when ACC was engaged. None of the ACC owners reported hitting anything with ACC engaged; and 5 people did not answer this question. The perception of ACC being helpful during stop-and-go traffic and on a curvy road was mixed. A slightly larger portion (48%) of participants thought that ACC would not be helpful in stop and go traffic, while a slightly larger portion (50%) though it could help in following a vehicle on a curve.

Table 6 Perceptions of ACC under various conditions

Variable	Category	Count	Percentage
Responding time to unexpected road hazard with ACC on	Slower	8	7.9%
	No change	62	61.4%
	Quicker	23	22.8%
	Did not know	8	7.9%
ACC could help in stop-and-go traffic	Yes, it could	42	41.2%
	No, it could not	49	48%
	Did not know	11	10.8%
ACC could help when following a vehicle on a curvy road	Yes, it could	51	50%
	No, it could not	42	41.2%
	Did not know	9	8.8%
ACC could help when the vehicle ahead brakes suddenly	Yes, it could	68	66.7%
	No, it could not	27	26.5%
	Did not know	7	6.8%

When asked about the actual usage of ACC under certain conditions, 48.5% (50 out of 103) of respondents had never turned ACC on in snow and rain, but 20.4% (n=21) had used ACC more than half the time. There were 68 (66.7%) participants who refused to use ACC in heavy stop-and-go traffic. On curvy roads, 54.4% (n=56) participants still kept ACC on more than half the time. Only 44.7% (n=46) had never used ACC under this situation.

As stated earlier, a description of ACC was provided at the beginning of the survey. Hence, all respondents can provide their opinions of ACC based on this description. There was a greater portion of ACC owners that strongly agreed with the statement “I trust ACC would work” when compared to non-ACC owners (Figure 6). However, there was a tendency toward trust by non-ACC owners as well with 59.2% that still indicated “agree” to this same statement. Upon further examination, 29.4% of the younger age group owned ACC, while only 17.1% of the older age group owned ACC.

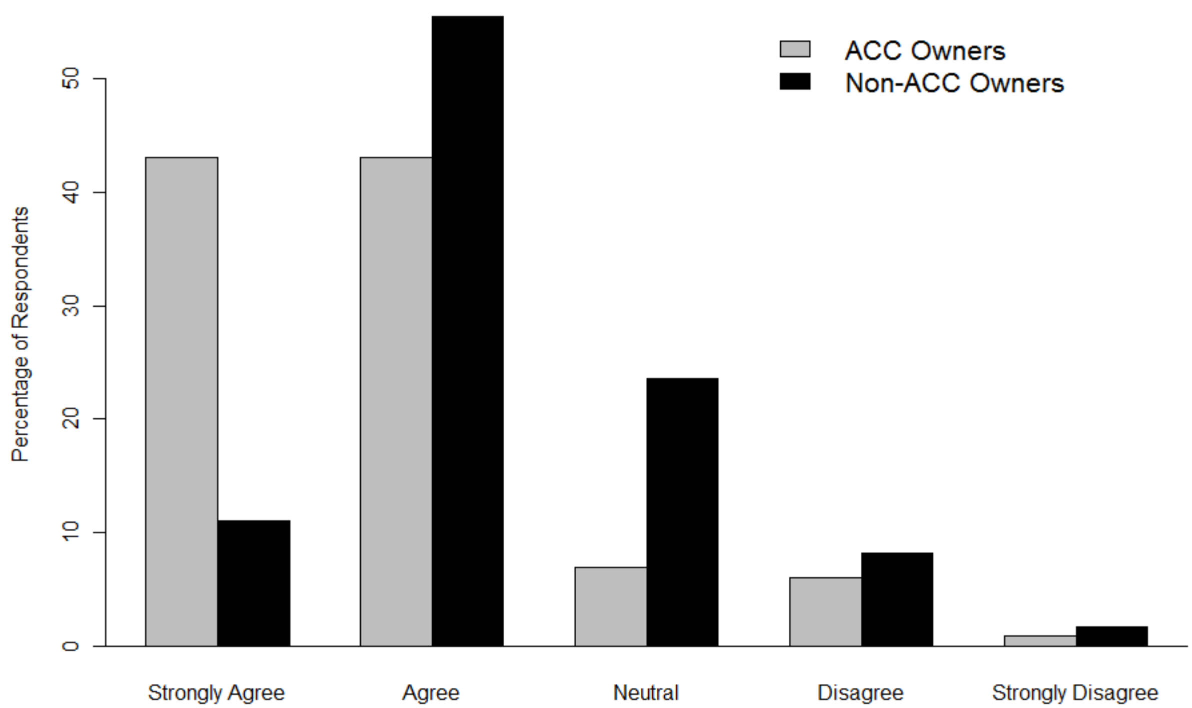


Figure 6 The distribution of drivers’ opinion towards “I trust ACC would work” among ACC owners and non-ACC owners

The opinions related to whether ACC owners trust ACC or not, and how much they trust ACC was not dependent on age group and gender differences. Figure 7 shows the interaction plots of percentage of participants who owned ACC by age and gender groups after eliminating the non-applicable (NA) values. T-tests were done between age and gender groups towards trusting of ACC. All the p values indicated that no statistical differences were observed in trust between age and gender groups (Table 7). Therefore, age and gender were not included in the logistic model on ACC trust.

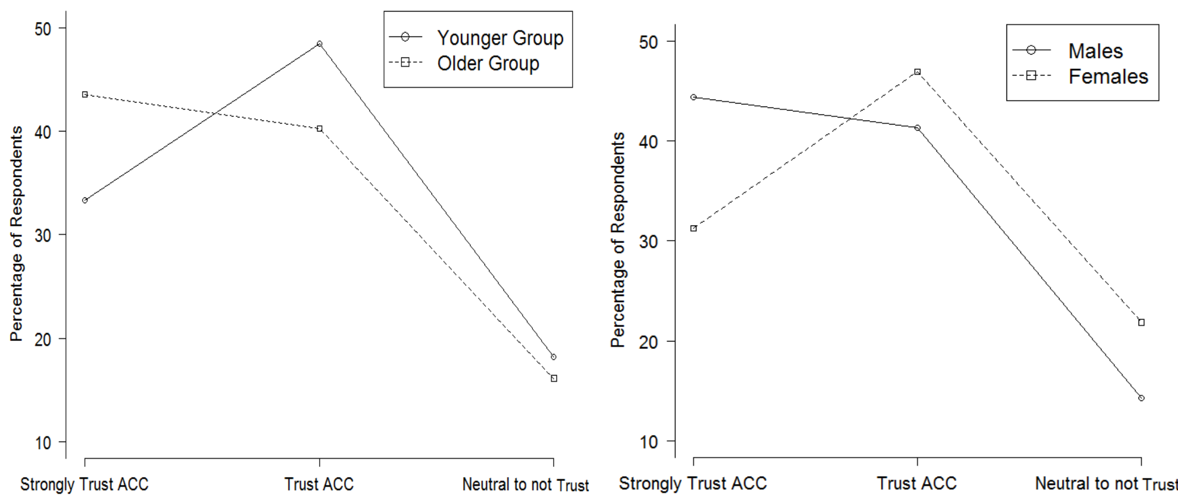


Figure 7 The distribution of drivers' opinion towards "I trust ACC would work" among Younger &Older group, and Males &Females

Table 7 t-tests for age and gender groups for ACC owners' trust towards ACC

	Age Group (Younger vs. Older)		Gender (Male vs. Female)	
Strongly Trust ACC	t(67.92) = -0.98,	p = 0.33	t(65.97) = 1.26,	p = 0.21
Trust ACC	t(63.95) = 0.75,	p = 0.45	t(61.26) = -0.51,	p = 0.61
Neutral to Not Trust ACC	t(62.37) = 0.25,	p = 0.81	t(53.74) = -0.88,	p = 0.38

Binary Logistic Regression Model: Characteristics of ACC Owners

A binary logistic model was developed to predict ACC ownership based on the characteristics of respondents (Table 8). The results showed that drivers who highly trust ACC were 6.05 times more likely to be ACC owners.

Table 8 Comparing ACC owners with non ACC owners

	ACC Owners (1), Non-ACC Owners (0)					
Variables	Estimate	Std. Error	z value	Pr(>|z|)	OR[a]	95% CI
(Intercept)	-2.03	0.35	-5.84	<0.0001		
Trust ACC	1.80	0.26	7.00	<0.0001	6.05	(3.67, 10.08)
Age: Young	0.81	0.27	3.04	0.002	2.24	(1.33, 3.76)
No. of People	0.18	0.09	2.03	0.042	1.19	(1.00, 1.44)
Toyota &Lexus Users	0.49	0.24	2.05	0.041	1.64	(1.02, 2.64)
Safety	-0.73	0.31	-2.31	0.021	0.48	(0.26, 0.90)
Specifications	-0.85	0.44	-1.92	ns[b]	0.43	(0.17, 1.00)
Style	-0.69	0.37	-1.85	ns[b]	0.50	(0.24, 1.04)
Null deviance:	540.47 on 533 degree of freedom					
Residual deviance:	466.69 on 526 degree of freedom					
AIC:	482.69					
Number of observations:	534					

[a]OR: Odds Ratio
[b] ns: not significant

ACC ownership was impacted by age. Those participants who were younger than 45 years old were 2.24 times more likely to own a vehicle with ACC than people who were in older groups. ACC owners were more likely (OR=1.19) to have additional people in their vehicles indicating that perhaps these owners have larger household sizes. Toyota or Lexus owners (41.5%, n=49) were also more likely to own ACC. The results indicated that they were 1.64 times more likely to own ACC than other brands owners.

The attributes “safety”, “specifications” and “style” were three factors that came from survey question of as the most important reason for choosing this current vehicle. Factor “safety” was significant while “specifications” and “style” were marginally significant (p=0.054 and p=0.064, respectively). The two marginally significant factors were kept in the model because they lowered the AIC value and thus made the model better fitted. Results showed that “equipped with ACC” was contradicted with “I wanted safety and quality”. In other words, people were willing to give up having ACC when given a choice between ACC and a vehicle that can ensure higher safety and quality (OR=0.48).

Perceptions and Trust in ACC

As shown in the results of the ACC ownership model, trust in ACC appeared to be associated with actual ACC ownership. Hence, in the second model, the hypothesis that drivers trust ACC because of their general perception of how ACC functions is examined. An ordered logistic model was used to examine this hypothesis and more specifically to predict the likelihood of increasing trust in ACC (Table 9) among ACC owners. Some owners knew the limitations of ACC while others were not as aware and may used ACC inappropriately in situations that require more driver intervention. The purpose of this model was to find factors that might influence drivers' trust in ACC, and whether that trust is warranted based on the capability of ACC.

The ordered logistic model suggested that factors related to perception of ACC and driver behaviors significantly influence ACC owners' trust towards ACC. The results indicated that feeling safe (AOR=7.96) and convenience (AOR=4.00) significantly increase the likelihood of highly trusting ACC systems among ACC owners. If the driver thought ACC would help him/her a lot when following the vehicle on a curvy road, then the driver was 3.09 times more likely to trust ACC. Two kinds of driver behaviors were found to be significant. Not surprisingly, people who seldom use ACC in flowing traffic were more likely to be in the group of "not trusting to neutral" (AOR=0.09). Using navigational technology (e.g., GPS) when ACC was on was also a significant factor in the model. This implied that respondents who seldom turned ACC on when using navigational technologies were less likely to trust ACC (AOR=0.19). Interactions between frequency of ACC use when traffic is flowing, and using navigational technology did not significantly affect the dependent variable. However, it was kept in the model to ensure a better model fit (smallest AIC). No other factors, including age, gender, Toyota or Lexus owners, and number of passengers in car were found significant in the model, nor were any other interactions between each factor in the model.

Table 9 Summary of ordered logistic model predicting ACC owners' perception of ACC

	Probability of Trust ACC: Not Trusting to Neutral (1), Trusting (2), and Highly Trusting (3)						
Variables	Comparison	Estimate	Std. Error	**t** value	Pr(>|z|)	AOR[a]	95% CI
(Intercept)	Not Trust vs. Trust	-2.12	0.86	-2.46			
(Intercept)	Trust vs. Highly Trust	0.86	0.85	1.02			
I feel safe using the ACC system	Strongly agree vs. Others	2.07	0.65	3.19	0.001	7.96	(2.37,31.36)
ACC is convenient to use	Agree vs. Disagree	1.39	0.60	2.31	0.021	4.00	(1.26,13.50)
The ACC will help me when following the vehicle on a curvy road	Much vs. Others	1.13	0.55	2.04	0.041	3.09	(1.07,9.51)
How often you use ACC when traffic is flowing	Seldom vs. Usually	-2.37	0.92	-2.57	0.010	0.09	(0.01,0.53)
How often you use ACC when using navigational technology	Seldom vs. More than half	-1.68	0.79	-2.12	0.034	0.19	(0.04,0.83)
Traffic Flowing*Using navigational technology	Seldom * Seldom	1.83	1.10	1.66	ns	6.22	(0.76,58.71)
Null Deviance:	195.54 on 93 degree of freedom						
Residual Deviance:	144.42 on 87 degree of freedom						
AIC:	160.4153						
Number of observations:	95						

[a]AOR: Adjusted Odds Ratio

Word Analysis (Comments)

An exploratory analysis on the respondents’ comments was conducted using a word cloud analysis. The survey included several comment fields with a total of 32.2% (n=38) of ACC owners expressing their views and opinions. There were 34 responses to one question: “[Q13] Does ACC create any new problems or safety concerns for you?” Among the 34 respondents, only one ACC owner gave a positive comment indicating that ACC can help release part of the driver’s attention to other non-driving tasks.

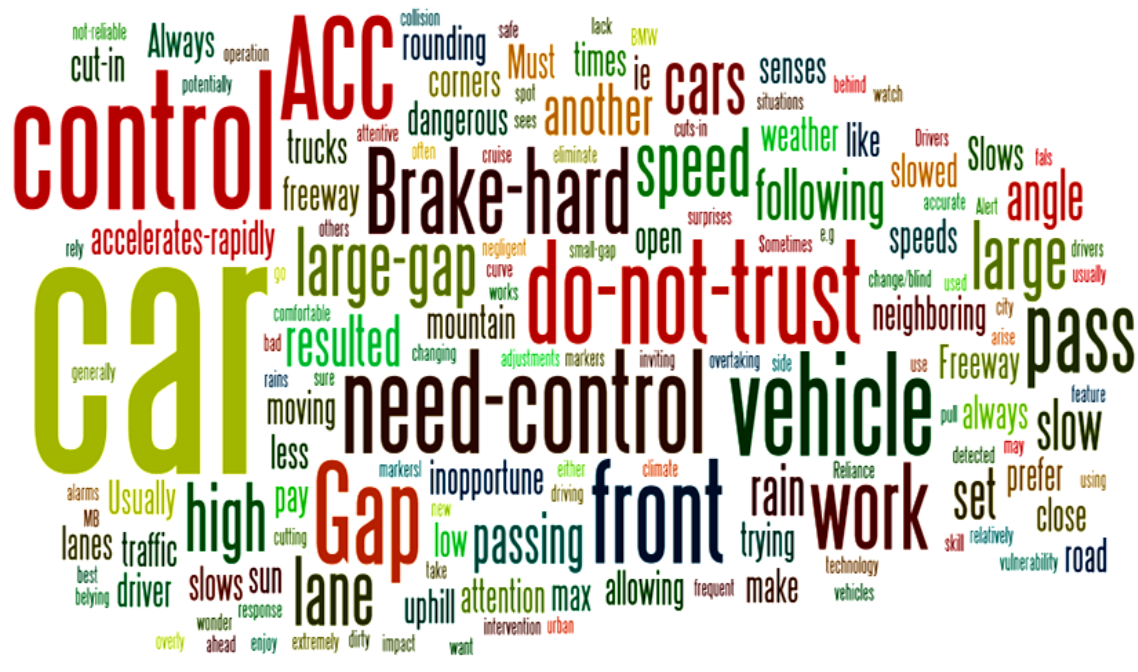


Figure 8 Word cloud analysis

A lexical (or word cloud) analysis was employed to examine key words from this question using two web-based word cloud analysis tools, the Public Comment Analysis Toolkit (PCAT) (Texifter LLC) and Wordle (Feinberg, 2011) (Figure 8). There were 18 comments that indicated “do not trust” or “need control”. The second set of key words were “brake or accelerate hardly” and “uncomfortable” (n=10). More specifically, respondents indicated that ACC often caused sudden brake or acceleration, especially when passing or when there was another car cutting-in. Respondents also discussed the “gap” between their vehicle and the vehicle in front (n=5). One respondent indicated that the car followed too closely to the vehicle ahead at high speed, while the other four respondents indicated that the gaps were too large and always invited other cars to cut-in.

A very simple ordered logistic model was used to examine the likelihood of trust in the system among people who provided comments and those who failed to offer feedback. The explanatory variable was binary, whether participants gave comments or not, while the dependent variable is the same as that in the trust in ACC model. A significant p value ($p=0.015$) was associated with whether giving comments or not. That is to say, if an owner provided comment(s) to the specific question, he or she was more likely to hold opinion ranging from neutral to not trust ($\beta= -1.00$) in ACC (AOR=0.34, 95% CI=[0.12, 0.89]).

Chapter Summary

This chapter showed the results of two logistic models, ACC ownership and trust in ACC, as well as the exploratory findings on respondents’ safety concerns. The binary logistic model showed that age, number of people usually in the vehicle, vehicle brand, and safety preference significantly determined ACC ownership. Among ACC owners, their trust in ACC was significantly affected their perceptions of ACC and their overall driving behavior. A word cloud analysis provides some additional insights on these drivers. More specifically, some drivers may have been able to recognize the limitations of ACC based on daily usage. These models provide a profile of drivers who use ACC and are of value because the results can give further suggestions on ACC improvement.

CHAPTER IV SUMMARY AND DISCUSSION

There are many benefits gained from advanced vehicle systems. However, actual experiences with certain technology may differ from their intended use and design. A survey conducted in Washington State was used to examine the likelihood to own as well as to trust ACC as influenced by perceptions and actual experiences to ACC.

In general, younger people have often been shown as more accepting of technology (Czaja, et al., 2006) when compared to older individuals, and this was also observed in the model of ACC ownership where younger respondents (less than 45 years old) were more likely to own a vehicle with ACC. It is interesting to note that ACC use is typically observed (Llaneras, 2006) more in older drivers given economic status compared to younger drivers. However, further analysis does suggest that younger people (less than 45 years old) were more interested in and had higher possibility to purchase vehicles equipped with certain advanced technologies, which seems contrary to the findings of Llaneras (2006). However, this can be explained by the mean age of the surveyed respondents (mean=56.34 year old, sd=14.57 years old). That is, although the age groups were separated into a younger and older group, the general driving population for ACC owners is the younger group which is still considered middle-age (i.e., between 30 to 45 years old) and this age group do typically have the economic capability to purchase intermediate to high-end vehicles.

ACC owners tend to have more people in their vehicles and this may be more indicative of the household size. More specifically, further examination showed that many survey respondents owned Toyota Siennas, a vehicle that is most widely used by larger households but also equipped with ACC as a standard feature. Owners of Toyota Siennas may be selecting this vehicle type because of its ability to hold more individuals, rather than the additional features available. It can also be hypothesized that additional family members would also be associated with more vehicle use, and driving longer distances. The option of ACC feature might assist them easy driving. Hence, this household size is confounded with car type, and further studies will be needed to examine this issue.

In this current study, drivers tend to highly trust ACC only after they owned ACC. Accordingly, it was important to identify what aspects of trust can lead to greater acceptance of the system. Trust in ACC seems to relate to drivers' perceptions of ACC and their driving behavior, both in positive and negative aspects. This has also been observed in other studies on the use of technology (Boer & Hoedemaeker, 1998; Rajaonah, et al., 2006b).

As mentioned earlier, ACC was designed to help people drive with more convenience. Shladover (1999) indicated that comfort and convenience were related to three aspects: (1) an increased perception of safety and security which is also related to actual safety benefits; (2) a reduction in the stress associated with less demanding driving tasks; and (3) a freeing up of the driver's attention for something other than driving. The second model (trust in ACC) could be implied across some of concepts brought up by Shladover (1999).

ACC may provide less stress to drivers if they perceive the system to appropriately make braking decisions at crucial moments. In one study, drivers who believed they had used the system correctly indicated they would continue to use the system (Tricot, et al., 2004). Further, drivers tend to monitor the system less if they trust their automated devices (Muir & Moray, 1996). Unfortunately, ACC usage on a curvy road may cause unnecessary acceleration or hard brake (Llaneras, 2006). However, this current research showed that drivers' perceptions related to ACC working properly on curvy roads was limited. The survey showed that over a quarter of the participants thought that ACC could help a great deal when on curvy roads, and engaged the system when they were in this situation. Additionally, the more they thought ACC could help on curvy roads, the more they would trust ACC systems.

Another major shortcoming of ACC was that the system has a maximum deceleration rate so it actually does not help when the vehicle ahead brakes suddenly. Since ACC is not capable of bringing the vehicle to a complete stop, drivers have been shown to have longer reaction time towards such situations (Rudin-Brown & Parker, 2004) and as result, incidence rate of rear-end crashes increased. The perceptions associated with a stopped lead vehicle were not found to be significantly associated with trust in ACC. However, it is still important to note this since over half of the ACC owners who responded perceived that ACC would help them in exactly this situation.

Alternatively, using navigational technology could also be regarded as distraction-related factor. Engaging in technological distractions inside the vehicle may actually encourage drivers to rely more on ACC and neglect the primary driving task (Lee, McGehee, Brown, & Marshall, 2006). Brown (2000) and Smiley (2000) showed that if drivers trust advanced technologies, such as ACC, they tend to use other available visual, cognitive and physical resources to engage in secondary tasks. Drivers may even regard such additional tasks as being more productive. However, in reality, these actions can result in greater driver distraction, and greater failures to detect and respond to changing events on the road (Brown, 2000; Rudin-Brown & Parker, 2004; Smiley, 2000; Wickens & Kessel, 1981). From the ordered logit model on trust, it is noted that people who usually use ACC and navigational systems are more likely to trust ACC. Hence, it is possible that people tend to share part of their attentions on secondary tasks (for example, using GPS) while ACC is on even though they are aware that it might increase crash risks (Bato, 2011).

In fact, they still try to share attentions to non-driving tasks in order to achieve productivity. This indicates that ACC owners thought the ACC could help drivers more by providing more opportunity to attend to non-driving tasks, which is consistent with the findings of Shladover (1999).

Word cloud analysis is utilized to identify ACC owners' comments regarding safety concerns and provide insights for future research and considerations for the design of future ACC systems. Although only 34 respondents shared their views on safety and non-safety issues with ACC, the findings could identify concerns toward ACC usage for the general driving population. For example, one ACC limitation discussed quite frequently in the comments related to sudden braking when they tried to restore vehicle control. This exploratory insight can help designers target the design-related issues with ACC. There was also concern related to the headway distance as a setting feature. For design purposes, future enhancements of ACC could include a distance setting system that can automatically adjust according to varying traffic conditions without interactions from the driver in safety critical situations.

Study Limitations and Future Research Topics

A major limitation of this current study is that "trust in ACC" was most likely confounded with ACC ownership. Although all respondents provided their perspectives on trust in ACC, the responses from ACC owners and non-ACC owners were based on different benchmarks. More specifically, ACC owners might provide their opinions upon actual experience, while non-ACC owners commented based only on the description of the system that was provided at the beginning of the survey.

As typical in surveys, respondents answered questions based on their remembrance of experiences. As such, there is a higher possibility that they provide answers not based on how a situation may actually unfold. Furthermore, the survey was mailed to households of potential ACC owners according to VINs and records from WS DOT. But it is possible that the household member that responded was not the primary owner of the vehicle with ACC. That said, every attempt was made to clarify the vehicle of interest and the intent of the survey.

The response rate for this survey study was 31.2% and this is fairly common among mail-back surveys. For greater accuracy and to reduce sampling bias, several researchers have suggested obtaining a random sample of 10% to 20% of non-respondents (Donald, 1967; Hagbert, 1968; Johnson, 1959; Miller & Smith, 1983). There is a challenge in obtaining additional information from non-respondents that may be of interest to examine in future studies.

There was one interested finding in that more BMW owners (about 14%) enrolled in the Washington State study when compared to another ACC study conducted in the state of Iowa (0.6%) (Dickie & Boyle, 2009). A future topic of interest could be to examine the differences between BMW ACC owners and Toyota or Lexus ones, and across these two states. The two car manufacturers have two very different ACC systems, use different radar/Lidar brands, operate differently, and have different settings and interfaces. However, when the study population was segmented to only ACC owners, there were actually very few BMW owners ($n \approx 5$) and additional recruitment would be needed to ensure statistical power.

Further research topics to explore include examining driver’s situation awareness, their driving demand while ACC is engaged, and the stress they may perceive with and without the system. Examining the safety benefits of ACC should not be based on drivers’ stated preferences only (as was done in this study), but should also be compared with the revealed preferences to the system (Lee, Gore, & Campbell, 1999; Rajaonah, et al., 2006b).

Research should also take into account the environment or situation awareness. Findings indicate that a reduction in driver workload does not necessarily lead to increasing situation awareness (Hoc, et al., 2009). Hence, future ACC systems could be designed to help drivers predict vehicle trajectory and identify collisions. Further research can focus on whether people tend to do secondary tasks more often while using ACC. The secondary task performance could be examined on simulators to see how drivers balance different tasks while driving.

Trusting can be both treated as antecedents and outcomes with some of the causes becoming the consequences and vice versa. In other words, ACC ownership might cause highly trust and that probably led to wrong usage and perceptions. Whereas, inaccuracy perceptions and usages of ACC will provoke over trust in the system, as shown in the trust in ACC model. Explorations of the reasons why drivers showed highly trust or distrust in the system could assist manufacturers further reminding or educating the users for the existing limitations. Further research on specific misuse and over trust cases could inform better design and improvement of advanced driver assistance system.

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APPENDIX A Washington ACC Survey

Figure 9 Washington ACC Survey

UNIVERSITY *of* WASHINGTON

Using Adaptive Cruise Control

Thank you for taking time to participate in our study and providing us information for the design of safe and convenient vehicles. This survey will take 5-10 minutes to complete.

Whether you have driven a vehicle with Adaptive Cruise Control (ACC) or not, we appreciate your participation in this study, and you are entitled to a $10 gift card redeemable at your choice of Starbucks, Walmart, or Barnes & Noble when you complete this survey.

Q1
Please enter the 5-digit invitation number that is found at the top left corner of your invitation letter.

What you think about Adaptive Cruise Control (ACC)

The following section is to be answered whether or not you have used ACC.
The car you own may have Adaptive Cruise Control (ACC). **This is a new technology different from regular cruise control.** Regular cruise control is found in most cars and maintains a constant speed without you keeping your foot on the accelerator pedal. ACC does this as well but it also **automatically slows your vehicle down without you pressing your foot on the brake pedal.** The ACC laser or radar sensors can detect moving vehicles in front of your own vehicle and, if required, slow your vehicle.

Q2
Based just on the description of ACC above, please state how much you agree or disagree with the following statements:

Statement:	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
A. I trust an ACC system would work	1	2	3	4	5
B. I would use ACC often	1	2	3	4	5
C. I feel that ACC would allow me to do other things while driving (e.g. use cell phone, map, radio, GPS, etc.)	1	2	3	4	5
D. I think ACC would reduce my stress while driving	1	2	3	4	5
E. ACC can be set to improve traffic flow (e.g. it can be set to follow vehicles at a *high* speed and *close* distance.) I would set ACC to this setting	1	2	3	4	5
F. ACC can be set to improve driver comfort (e.g. it can be set to follow vehicles at a *low* speed and *far* distance.) I would set ACC to this setting	1	2	3	4	5
G. More technology in my car is always better	1	2	3	4	5
H. In general, technology is beneficial and is an important part of my life	1	2	3	4	5

Page **1** of **7**

Q3
What is your vehicle's make, model, and year?
A. Make:

B. Model:

C. Year:

Q4
If you purchased this same vehicle again, would you want it to have ACC?
- ☐ Yes
- ☐ No
- ☐ I don't know

Q5
Did you purchase your vehicle new or used?
- ☐ New
- ☐ Used

Q6
I selected this vehicle primarily because: *(Please select only one)*
- ☐ I wanted the basic specifications (e.g. seating capacity)
- ☐ I liked the styling and looks
- ☐ I wanted safety and quality
- ☐ The cost is within my budget
- ☐ I liked the features offered (e.g. sunroof)
- ☐ The vehicle has ACC
- ☐ I did not choose this vehicle

Q7
Do you currently own a vehicle with ACC?
- ☐ Yes
- ☐ No

If "No", why not? *(Please check all that apply)*
- ☐ It was not an option on my vehicle
- ☐ It never occurred to me to look for it when I purchased the vehicle
- ☐ I thought it would be a nuisance or distraction
- ☐ I don't trust that it will work
- ☐ It was only available with other options that I didn't want
- ☐ It was not worth the extra cost
- ☐ I was not the person who decided to get this vehicle and its associated options
- ☐ I have never heard of it

If you answered "No" to Q7, please skip to **Q23** (on the back, **page 7**)

How you feel about using ACC

Please skip to Q23 if you have never used ACC. **The following questions are only to be answered if you have used ACC.** These questions are based on your actual use of ACC.

Q8
How long have you owned/driven a vehicle with Adaptive Cruise Control (ACC)?

A. Years

B. Months

Q9
Approximately how many miles have you personally driven in this vehicle?

Q10
Since you've owned this vehicle, about what percentage of time do you use ACC while driving? (Please respond with a percentage – *e.g. 50%)*

%

Q11
How did you learn to use ACC? *(Please check all that apply)*

- ☐ Dealer Demonstration
- ☐ Owner's manual
- ☐ Internet, Magazine, or similar resources
- ☐ Self-taught
- ☐ Previous Owner
- ☐ Did not learn yet
- ☐ Other, please specify:

Q12
Was there anything difficult about learning to use ACC?

- ☐ Yes
- ☐ No

If "Yes", please explain:

Q13
Does ACC create any new problems or safety concerns for you?

- ☐ Yes
- ☐ No

If "Yes", please explain:

Q14
<u>Based on your actual use of ACC</u>, please state how much you agree or disagree with the following statements:

Statement:	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*
A. I feel safe using the ACC system	1	2	3	4	5
B. ACC is convenient to use	1	2	3	4	5
C. Using ACC reduces my stress while driving	1	2	3	4	5
D. I tend to use the radio and/or other vehicle accessories more often with ACC on	1	2	3	4	5
E. I tend to make and receive phone calls (i.e. "hands-free") more with ACC on	1	2	3	4	5
F. I tend to use a paper map or other similar material more often with ACC on	1	2	3	4	5
G. I tend to use GPS or other navigational technology more often with ACC on	1	2	3	4	5
H. I tend to eat or drink more with ACC on	1	2	3	4	5
I. In general, I use ACC often	1	2	3	4	5

Q15
How quickly do you notice and react to unexpected road hazards when ACC is turned on, compared to when it is turned off? *(Please check only one response)*

- ☐ Much slower
- ☐ Slower
- ☐ Neither slower nor quicker
- ☐ Quicker
- ☐ Much Quicker
- ☐ Don't know

Q16
Have you ever hit something in front of your vehicle with the ACC turned on?

- ☐ Yes
- ☐ No

If "Yes", please describe the situation:

Q17
Please rate how much you think that ACC would help you in avoiding a crash with the vehicle in front of you if…

Statement:	*A Great Deal*	*Much*	*Somewhat*	*Little*	*Not at all*	*Don't know*
A. You are following the vehicle in stop-and-go traffic	1	2	3	4	5	6
B. The vehicle stopped in your lane	1	2	3	4	5	6
C. You are following the vehicle on a curvy road	1	2	3	4	5	6
D. You are following a vehicle that brakes suddenly, as if for an emergency	1	2	3	4	5	6

How you adjust and use ACC

This section is related to how you adjust and use ACC and how this differs from your previous driving habits.

Q18

Please rate how often you use ACC in the following conditions:

Statement:	*Always*	*Usually*	*About half the time*	*Seldom*	*Never*	*Don't know*
A. Rain or snow	1	2	3	4	5	6
B. Low/no sunlight	1	2	3	4	5	6
C. On interstates (i.e. I-5, I-90, I-405, etc.)	1	2	3	4	5	6
D. On highways (i.e. US-2, US-12, US-101, etc.)	1	2	3	4	5	6
E. In traffic that is flowing	1	2	3	4	5	6
F. In heavy "stop-and-go" traffic	1	2	3	4	5	6
G. Freeway on- or off-ramps (i.e. entering or exiting)	1	2	3	4	5	6
H. On city streets with traffic lights	1	2	3	4	5	6
I. On curvy roads	1	2	3	4	5	6
J. On roads with lower speed limits	1	2	3	4	5	6
K. When tired or otherwise impaired	1	2	3	4	5	6
L. When using the radio and/or other vehicle accessories	1	2	3	4	5	6
M. When making or receiving calls with a hands-free headset	1	2	3	4	5	6
N. When using a paper map or other similar material	1	2	3	4	5	6
O. When using a GPS receiver or other navigational system	1	2	3	4	5	6
P. When eating or drinking	1	2	3	4	5	6

Q19
Do you normally change your following distance while you are using ACC?

- ☐ I always set the same following distance
- ☐ I change the amount of following distance as conditions change
- ☐ My ACC does not allow me to change the following distance
- ☐ I don't know how to change my following distance
- ☐ Other, please specify:

Q20
At what following distance do you usually set your ACC?

- ☐ At the shortest setting, which is as close to the lead vehicle as my ACC allows
- ☐ At a medium setting
- ☐ At the longest setting, which is as far from the lead vehicle as my ACC allows
- ☐ Other, please specify:

Q21
Please identify the length of your following distance when using ACC, compared to when not using ACC:

- ☐ Smaller distance
- ☐ Slightly smaller distance
- ☐ About the same
- ☐ Slightly larger distance
- ☐ Larger distance

Your opinion on ACC

These questions relate to how you feel about ACC and how it affects you as a driver.

Q22
For each of the following statements, please state how much you agree or disagree:

Statement:	*Strongly Agree*	*Agree*	*Neutral*	*Disagree*	*Strongly Disagree*	*Not Applicable*
A. I tend to change lanes less frequently when using ACC	1	2	3	4	5	6
B. I set ACC to follow vehicles at a high speed and close distance	1	2	3	4	5	6
C. I set ACC to follow vehicles at a low speed and far distance	1	2	3	4	5	6
D. The sounds made by the ACC system are easy to understand	1	2	3	4	5	6
E. The lights/symbols on the ACC system are confusing	1	2	3	4	5	6
F. The ACC following distance setting is easy to understand	1	2	3	4	5	6
G. The ACC cruise speed setting is confusing	1	2	3	4	5	6
H. More cars cut me off or pull in front of me when I am using ACC	1	2	3	4	5	6
I. ACC sometimes locks onto a vehicle other than the vehicle immediately in front of me	1	2	3	4	5	6
J. I rely on ACC to reduce my stress when driving	1	2	3	4	5	6
K. I am a safer driver now that I use ACC	1	2	3	4	5	6

About You

Q23
How old are you?

[ ]

Q24
What is your gender?
- ☐ Male
- ☐ Female

Q25
On average, how many people are in your vehicle, including yourself?

[ ]

Q26
How many miles do you typically drive in a seven-day week?

[ ]

Q27
Do any of these conditions affect your driving ability? *(Please check all that apply)*
- ☐ Vision Difficulties
- ☐ Hearing Difficulties
- ☐ Dexterity Difficulties (e.g. arthritis)
- ☐ Difficulty turning your head/neck
- ☐ None of the Above
- ☐ Other, please specify:

[ ]

Future Research
If you would be willing to participate in future University of Washington research studies, please fill in the information below. This is completely optional and volunteers are contacted as needed. The information you provide will be kept on file, however not all volunteers will be contacted for future studies.

Q28
Would you like to take part in a telephone interview?
- ☐ Yes
- ☐ No

Q29
Would you be willing to participate in future studies at the University of Washington if we compensate you for your time and travel? *(Please check all that apply)*
- ☐ On-road study
- ☐ Simulator study

Q30
If you would be interested in taking part in any future studies, please provide us with the following details:
Name (**optional**): ______________________ Phone : ______________________
Best time of day to call: ______________________

Thank you for completing our survey!
Please select the $10 gift card of your choice. The gift card compensation processing will be kept separate from your survey to ensure your anonymity.

Q31
Gift Card Choice: *(Please check only one)*
- ☐ Walmart
- ☐ BARNES&NOBLE BOOKSELLERS
- ☐ STARBUCKS COFFEE

Q32
Preferred Mailing Address for gift card:

[ ]

THANK YOU FOR YOUR PARTICIPATION
PLEASE FOLD AND TAPE THIS SURVEY CLOSED BEFORE MAILING

APPENDIX B Number of Respondents Indicating the Vehicle Make and Model

Table 10 Number of respondents indicating the vehicle make and model

Vehicle Make &Model (Series)	Count	Vehicle Make &Model (Series)	Count
Acura RL	4	Acura RSX	1
Acura TL	1	Audi A3	1
Audi A4	3	Audi A5	1
Audi A6	4	Audi A8L	2
Audi Q5	2	Audi Q7	4
Audi S5	2	BMW (unknown model)	1
BMW 128i	2	BMW 325 Series	10
BMW 328 Series	17	BMW 330 Series	6
BMW 335 Series	8	BMW 525 Series	4
BMW 528 Series	3	BMW 530 Series	6
BMW 535 Series	7	BMW 538xi	1
BMW 545i	1	BMW 645	1
BMW 745 Li	1	BMW 750 Series	5
BMW X3	4	Cadillac CTS	2
Cadillac DTS	21	Cadillac Deville	4
Cadillac Escalade	1	Cadillac XLR	3
Cadillac STS	8	Chevrolet Colorado LS	1
Chevrolet Impala	1	Chevrolet Marlibu	1
Chevrolet Silverado	2	Chevrolet Tahoe	3
Chrysler 300 Series	8	Chrysler Town and Country	1
Dodge (unknown model)	1	Dodge Durango	2
Dodge Ram1500	2	Dodge Ram2500	2
Ford Edge	1	Ford F150	2
Ford F250	1	Ford Sport Track Pickup	1
GMC Suburban	1	GMC Yukon	4
Honda Accord	2	Honda Civic	2
Honda CR-V	5	Honda Fit	2
Honda Odyssey	2	Honda Pilot	1
Honda S2000	1	Hyundai Elantra	1
Hyundai Sonata	1	Infiniti G35 Series	15
Infiniti G37 Series	3	Infiniti M35 Series	11
Infiniti M45	3	Infiniti EX35	3
Infiniti FX35	7	Infiniti FX45	3
Infiniti QX4	2	Infiniti QX56	3
Infiniti TX35	1	Jaguar S-Type	4
Jaguar XF	2	Jaguar XK	1
Jeep Grand Cherokee	1	Kia Rio	4
Kia Sedona	1	Land Rover Sport	1
Lexus 350	4	Lexus 400H	2
Lexus 430	2	Lexus 450H	1
Lexus ES330	1	Lexus ES350	19
Lexus GS350	5	Lexus GS460	1
Lexus GX Series	3	Lexus IS Series	20
Lexus LS11	1	Lexus LS430	12
Lexus LS460	6	Lexus LX470	1
Lexus LX500	1	Lexus RH400	1

Table 10 continued Number of respondents indicating the vehicle make and model

Vehicle Make &Model (Series)	Count	Vehicle Make &Model (Series)	Count
Lexus RX Series	37	Lincoln Aviator	1
Lincoln MKS	5	Lincoln MKT	1
Lincoln MKZ	1	Mazda 3	1
Mazda Protege	1	Mercedes Benz (unknown model)	1
Mercedes Benz 220	1	Mercedes Benz 500	1
Mercedes Benz CL500	1	Mercedes Benz CLS550	4
Mercedes Benz E55	1	Mercedes Benz E63	1
Mercedes Benz E350	1	Mercedes Benz E500	1
Mercedes Benz GL Series	2	Mercedes Benz ML320	4
Mercedes Benz ML350	6	Mercedes Benz ML500	4
Mercedes Benz S55	1	Mercedes Benz S65	1
Mercedes Benz S430	1	Mercedes Benz S500	1
Mercedes Benz S550	2	Mercedes Benz SL500	1
Mercedes Benz R320	2	Mercedes Benz R350	1
Nissan Pathfinder	8	Porsche Boxster	1
Range Rover SuperCharges	1	Subaru Outback	1
Toyota (unknown model)	1	Toyota 4Runner	2
Toyota Avalon	66	Toyota Camry	3
Toyota HighLander	3	Toyota Prius	4
Toyota RAV4	3	Toyota Senica	1
Toyota Sequoia	1	Toyota Sienna	47
Toyota Tacoma	1	Toyota Tundra	3
Volkswagen Jetta	3	Volkswagen Passat	2
Volkswagen Touareg	2	Volvo S60	1
Volvo S80	1	Volvo XC70	2
Unknown make & model	5		