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Evaluation of fueling our future program: Consumer acceptance of biofuels in Iowa

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Evaluation of fueling our future program: Consumer acceptance of biofuels in Iowa

by

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TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

NOMENCLATURE

USEPA	United States Environment Protection Agency
RFS2	Renewable Fuel Standards: Final Rule applies to most transportation fuel used in the US
GHG	Greenhouse Gases
FFV	Flex Fuel Vehicles
E0	No Ethanol, Unleaded Gasoline
E10	Low-level blend compose of 10% ethanol 90% gasoline
E15	Ethanol blend fuel composed of 10.5% -15% ethanol
E85	High-level ethanol- gasoline blend composed of 51% - 83% ethanol depending on the season
TAC	Technical Advisory Committee
SRS	Statistical Research Services
IDALS	Iowa Department of Agriculture and Land Stewardship

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Lastly, the researcher would like to graciously thank her advisor Dr. Shauna Hallmark and Committee Members Dr. Jing Dong and Dr. Sebastien Pouliot for their guidance and constructive criticism needed to successfully complete this thesis. As well as the students who assisted in coding the surveys.

ABSTRACT

In Iowa, 53 percent of the corn that is harvested is used for ethanol production. Almost two-fifth of the ethanol that is generated is used for fuel. The distribution of biofuels increased by 0.7 percent in 2014 due to the rise in the sale of ethanol. If Iowa continues to allocate biofuels at the rate of 0.7 percent per year, the set target of replacing 25 percent of gasoline with biofuels by 2020 would not be satisfied. This underscores the need for programs such as “Fueling our Future. As part of the program, surveys were conducted at various gas stations in Iowa. The purpose of these surveys was to investigate consumer fuel choices as well as the reasoning behind those choices. By doing so, it was possible to determine the consumer acceptance and awareness of different biofuel blends such as E10, E15, E20, E30 and E85.

CHAPTER 1. INTRODUCTION

1.1 Background and Motivation

Transportation is essential to the daily activities of humans as well as the growth of the economy. However, the transportation sector is also a major contributor to fossil fuel and greenhouse gas emissions. Climate change poses a serious threat to the environment and to human health. Moreover, the depletion of fossil fuels creates the urgent need to develop and promote viable alternative fuels. In other words, fossil fuels are non-renewable, hence the need for renewable energy to ensure energy sustainability in the future. When compared to alternative fuel such as Ethanol, Natural Gas, Electricity, Biodiesel, Hydrogen, and Propane, Biofuel has been among the most promising alternative for a number of reasons, including that it can be used directly in conventional engines without major modifications. The Iowa Renewable Fuels (**1**) stated that over the last decade, the ethanol industry in the U.S. has prospered, with more than 200 corn-ethanol biorefineries across the nation with the capacity to produce more than 15 billion gallons of ethanol.

There is a vast number of literature available regarding the effects of ethanol-gasoline blends, on the engine's performance, fuel efficiency and emissions. However, despite being the leading source of alternative fuels in the United States, government officials and policy makers know very little about the public attitude toward the expanding and new biofuel related policies. The future of biofuels cannot solely depend on effectiveness or the efficiency but also on the social and economic climate. An individual's behavior is typically guided by their attitude towards an idea or product as well as the norms established by society. Therefore, it is essential to gain an understanding of consumers' behavior to understand how a product will be accepted.

1.2 Scope of the Problem

Iowa is leading US for ethanol production. For this reason, the Iowa General Assembly legislated an act in 2006 (H.F.2754) with the objective to replace 25 percent of the petroleum used in the formation of gasoline with biofuels by 2020. Subsequently, the Iowa Department of Agricultural and Land Stewardship and the Iowa Department of Transportation initiated a pilot program called Fueling the Future in 2015. The objective of this thesis is to gain a better understanding and evaluate consumer awareness to ethanol-based fuel in Iowa. Therefore, this thesis looks at consumers' knowledge and the determinants of that knowledge to understand the factors affecting higher blends ethanol demand. This study can also help to formulate policies that will encourage the use of ethanol in vehicles.

CHAPTER 2. LITERATURE REVIEW

2.1 Alternative Fuel and Transportation

According to the US Environmental Protection Agency (**2**), the transportation sector is a major contributor to greenhouse gas emissions, and accounts' for about 26 percent of the total greenhouse gas emission (GHG) in the U.S. as seen in Figure 2-1below. Additionally, the majority of GHG is Carbon Dioxide (CO_2), which is from the combustion of petroleum-based products like gasoline from passenger cars and light-duty trucks. In addition, carbon monoxide, methane (CH_4), nitrous oxide (N_2O) and hydrofluorocarbon (HFC) are also emitted during fuel combustion but in relatively smaller amounts.

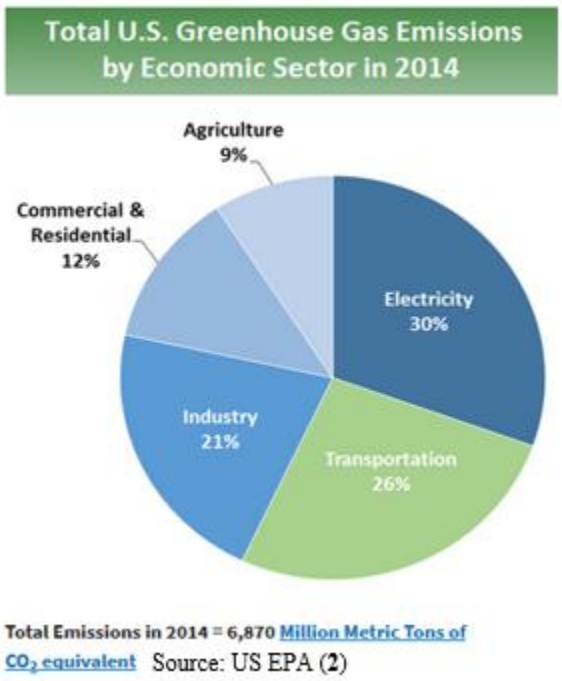

Figure 2-1: Total US Greenhouse Gas Emissions per Sector in 2014

GHG emissions from transportation have increased over the years, largely due to the increase in the number of miles driven, which is influence by the population, an economic growth and by prices for refined petroleum products. Strogen and Horvath (2013) states that GHG emissions have increased from 1.5 to 1.8 billion of CO_2 equivalent over 100 years

between 1990 and 2008 (**3**). As a result, governments around the world are implementing regulations and programs to reduce greenhouse emissions for the transportation sector, (**4**).

The transportation industry is a major component in any comprehensive long-term climate change mitigation strategy. Strategies includes the promotion of vehicle efficiency, use of alternative transportation fuels, travel demand reduction and lower greenhouse gas travel modes. The United State has historically pushed biofuel-blending volumetric mandates and offered tax incentives to support corn-based ethanol and soybean-based biodiesel (**4**).

Currently, oil, coal and natural gas supply around 90 percent of global energy use (**5**). However, due to the heavy reliance on fossil fuels, it has raised different issues such as rising energy prices, energy security concerns, long run supply, climate change, environmental degradation and impact on human health. Therefore, there is various research being done to determine what can be done to minimize the dependence of fossil fuels. The transportation sector requires alternative means to substitute for fossil fuels to meet State, National and International Greenhouse Gas reduction goals (**6**). Since 1999, in the US the number of ethanol production facilities have quadrupled, where in 2006 the ethanol imports have peaked which has influenced the US to consider ethanol infrastructure to supply domestic, predominantly in the Midwest.

Leiby et al. (1997), assert that the introduction rate of alternative fuel vehicle will be an important influence on the time path of fuel use and emissions and the sustainability of transportation patterns (**7**). Biofuel can be used to drastically reduce greenhouse gas emissions from road transport over a period. The Low Carbon Vehicle Partnership (LCVP) states that the level of Greenhouse saving associated with the conversion of wheat to ethanol varies between

7 – 77 percent (**7**). This is a vast range because greenhouse gas savings greatly depend on the production of biofuel or bioethanol.

On an international level the British House of Commons Environmental Audit Committee (**8**) strongly believes that the Government should ensure that its biofuel policy balance greenhouse gas emission cuts with wider environmental impacts, so that biofuels are only used where they contribute to sustainable emissions reductions. Road transport emissions could be reduced by 14 percent from the 1990 levels through a combination of vehicle efficiency savings, eco-driving, changes in travel behaviors, efficiency in freight transport and including aviation in the European Emissions Trading Scheme.

The Committee noted that developing countries can potentially benefit from the new sustainable biofuel market in the European Union, because it would improve economic conditions hence securing international sustainability standards for agricultural products. In particular, the rural area economy would benefit from increased demand for agricultural commodities.

The Renewable Energy Directive 2009/28/EC made it mandatory that EU member countries ensure that by 2020 fossil fuel used in the Transportation Sector contains 10 percent biofuel, as well as fulfil at least 20 percent of its total energy needs with renewable fuels by that same year. In the United States, the US Environmental Protection Agency (EPA) Renewable Fuel Standard Program, RFS2 requires sales of 36 billion gallons of renewable fuels in the United States by 2022. The EPA also extended the limit for the blending ethanol with gasoline from 10 percent (E10) to 15 percent (E15), however the higher limit is applied to vehicles that was manufactured after 2001, and older vehicles are covered by a partial waiver. To comply with the RFS2, there are a greater use of a fuel blend of 85 percent denatured

ethanol (E85) by flex fuel vehicles (FFVs), hence there are approximately 20 million FFV in use in the US which can use any mixture of E85 and E10, (**9**). It is important to note that almost 95% all US gasoline is blended with 10 percent ethanol, as well as the US Energy Information Administration (**10**) tracks the fuel component through the data it collects from refiners, importers, large blending terminals and ethanol producers. It was recorded that over the years the use of ethanol-free gasoline (E0) by fuel consumers has declined but the consumption of ethanol blends E15 and E85 have increased (**11**).

Liu et al. (**9**) conducted a research on consumer choice of E85 denatured ethanol fuel blend regarding price and availability. The research uses consumption data for Minnesota, North Dakota and Iowa, where they determine the demand of aggregate E10 to E85 and gasoline (this gasoline was noted to be considered E10) depends on the price, availability and compatibility. *Figure 2-2* below illustrate the use of E85 in the United States equivalent to gasoline gallons for Minnesota, North Dakota and Iowa.

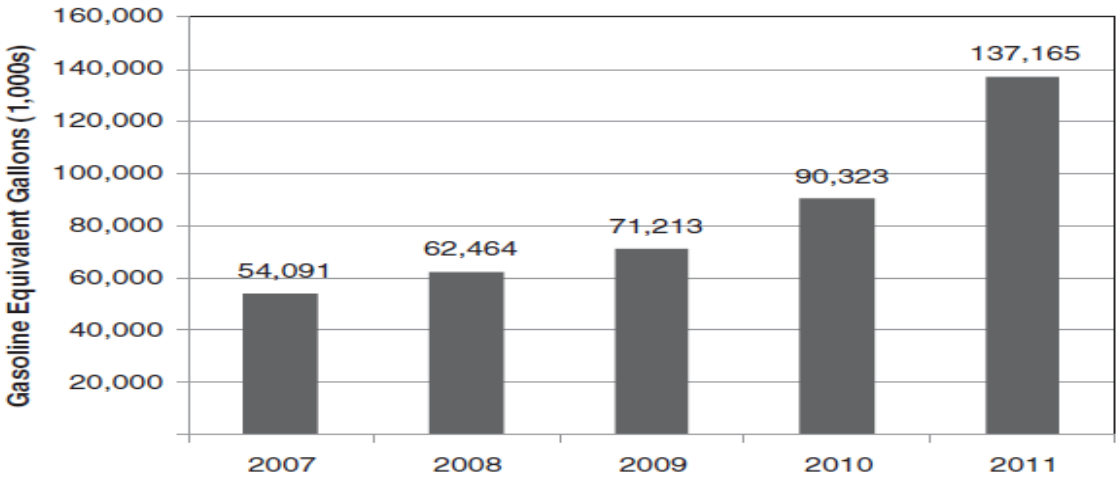

Figure 2-2: Energy Information Administration's estimates of E85 use in United States
Source: Liu et al (**9**)

Ideally, E85 means the blend is made up of 85 percent ethanol and 15 percent gasoline, however this is not the case, the blending ratio varies from 51 percent to 83 percent ethanol, and it is to adjust for a lower volatility of ethanol relative to gasoline for the wintry weather.

2.2 Alternative Fuel and Iowa

Iowa ranks first and second in the production of ethanol and biodiesel, respectively due to the agricultural and manufacturing culture that produces renewable energy such as wind energy, ethanol and biodiesel (**12**). Iowa ethanol production capacity in the United States has significantly increased from 440 million gallons in 2000 to 4.1 billion gallons in 2016. According to the 2016 Retailers Fuels Gallon Annual Report by the Iowa Department of Revenue (**13**), about 1.5 billion gallons of fuel was sold in Iowa where 1.4 billion gallons of that sales was ethanol blend in 2016. Additionally, 147 million gallons of pure biofuel were sold, which was 9.2% of all gasoline fuel sales. Furthermore, approximately 85% of the sales was E-10, and 0.8% was E-85. The success of the ethanol production has simulate the economic growth and added over 43,000 jobs in Iowa. (**14**)

2.3 Consumer Awareness of Alternative Fuels

Despite a significant increase in the use of the biofuels' consumption is relatively low, especially in western countries, compared to that of gasoline products. Tsagarakis et al. (**15**) considered the reason could be that the introduction of these new fuel and public opinion are not quite established yet. Their paper examines biofuel acceptance in the region of Thrace located in the North Eastern Greece using a fully structure questionnaire. They used logistic regression and tobit regression to evaluate the responses. They find that most of the respondents prefer to save energy rather than using alternative energy. Despite that respondents believed that the use of biofuel can be an effective solution against climate change and the energy problem. Tsagarakis et al showed that there are a severe lack of information, specifically

young people and less educated people. However, Cacciatore et al (**16**) found that older respondents in their study tend to agree more with the idea that biofuel/ethanol cause more damage to environment than gasoline. It was assumed that the younger respondents have a greater sense of awareness and optimism in improving and managing the environment through technology.

Similarly, a study conducted in North Carolina and Tennessee to evaluate the public perception of bioenergy specifically regarding biofuels for transportation, using surveys during fall 2013 and spring 2014. The finding revealed that price and vehicle compatibility were the key factors in their choice of biofuels over gasoline at the pump. They too concluded that there is a significant lack of information about both bioenergy and biofuel communicated to the public. It was suggested that the local and national government needs to have a consistent and straightforward message delivered through appropriate media channels to the public to clear up any misconceptions about alternative fuels. Radics et al (**17**) conducted study using telephone survey revealed that respondents who said they were somewhat informed about biofuel, ethanol agreed that using biofuel is an innovative idea. They agreed that using corn to produce ethanol was a promising idea. However, despite the positive results, the overall survey data suggested that the favorable attitude toward biofuels were not particularly strong.

Jensen et al (**18**) evaluated consumers' willingness to pay for E85 from corn, switchgrass, and wood residues, and discovered that consumers are more willing to pay more for E85 from switchgrass than corn. This is due to the belief that the land should be used for food rather than fuel, in other words, using corn for ethanol production was viewed to negatively impact food security. Also, females were willing to pay more for E85 regardless of the feedstock type than the males, while the older respondents who were from the South and

Midwest were willing to pay less than the younger respondents in those areas. Overall in their study it was surprising that the respondents were less willing to pay for E85 produced from corn.

2.4 Socioeconomics Influences

The transport system is closely associated to the socio-economic changes of a society where the mobility and levels of accessibility are the core of this relationship. The efficiency of the transport system has provided economic and social opportunities and benefits resulting in improved accessibility to markets, employment and investments. On the other hand, if the system is not up to par, there is an economic cost such as lower quality of life (**19**).

The introduction of biofuel development will impact several sectors, including Agriculture, Energy and Transportation. Hence, the trends in public opinion, and household income among other factors can give an insight about the future usage or adoption of alternative fuels (**20**).

Consumer behavior is a major factor in choosing a product or service. There are numerous factors involved in the decision process. These include personal factors such as:

- Education
- Occupation
- Age
- Economic Condition
- Lifestyle
- Personality

CHAPTER 3. METHODOLOGY

3.1 Data Collection

Survey Development

The survey used to assess consumer acceptance of ethanol was developed in conjunction with the project Technical Advisory Committee (TAC) and Survey Research Service (SRS) from the Center for Survey Statistic and Methodology at Iowa State University. The Technical Advisory Committee consist of the representatives from Iowa Department of Agriculture and Land Stewardship (IDALS), Iowa Department of Transportation (DOT) and the project researchers. SRS conducted the infield survey and reviewed survey wording to ensure it was understandable to respondents. Also, the surveys were tailored based on the fuel available at the participating stations, but the general template was uniform so that the questions asked were consistent.

The survey structure included the type of fuel the consumer purchased and the reason for their selection, vehicle model, type and year and why the consumer did not select a higher ethanol blend depending on the fuel purchased. Additionally, the age, gender and other demographic information was requested in the survey.

Furthermore, participants who were under the age of 18 were excluded as it required parental approval which was not feasible under the circumstances of the collection method.

It is important to note that this method was chosen to prevent hypothetical bias, as individuals tend to respond differently to hypothetical scenarios than what they actual do in the real time in the same scenario.

Participating Stations

A list of stations that offer biofuel blend was obtained from the Iowa Renewable Fuels Association. As well as additionally information about the stations was provided by the Iowa Economic Development Authority (IEDA) and the Iowa Department of Agriculture Land Stewardship (IDALS). Stations were selected based on the type of fuel blends sold to ensure there was a representative sample of different mid-range blends. Location of these stations was very important as the surveyors were based in Ames, Iowa, hence the travel time and cost to travel to other areas of the state were considered. The list of prospective sites was compiled and each of which was contacted by members of the TAC. Subsequently, the list was narrowed down due to different circumstance. The surveys included customers from 6 Chain Gas Station from 18 locations in nine counties across Iowa as seen in Figure 3-1 below. The 6 Chain Stations were: -

- Kum & Go
- Fast Stop
- Sapp Brothers
- Best Foot Mart
- Co-Op Expressway
- BP/ Mother Hubbard

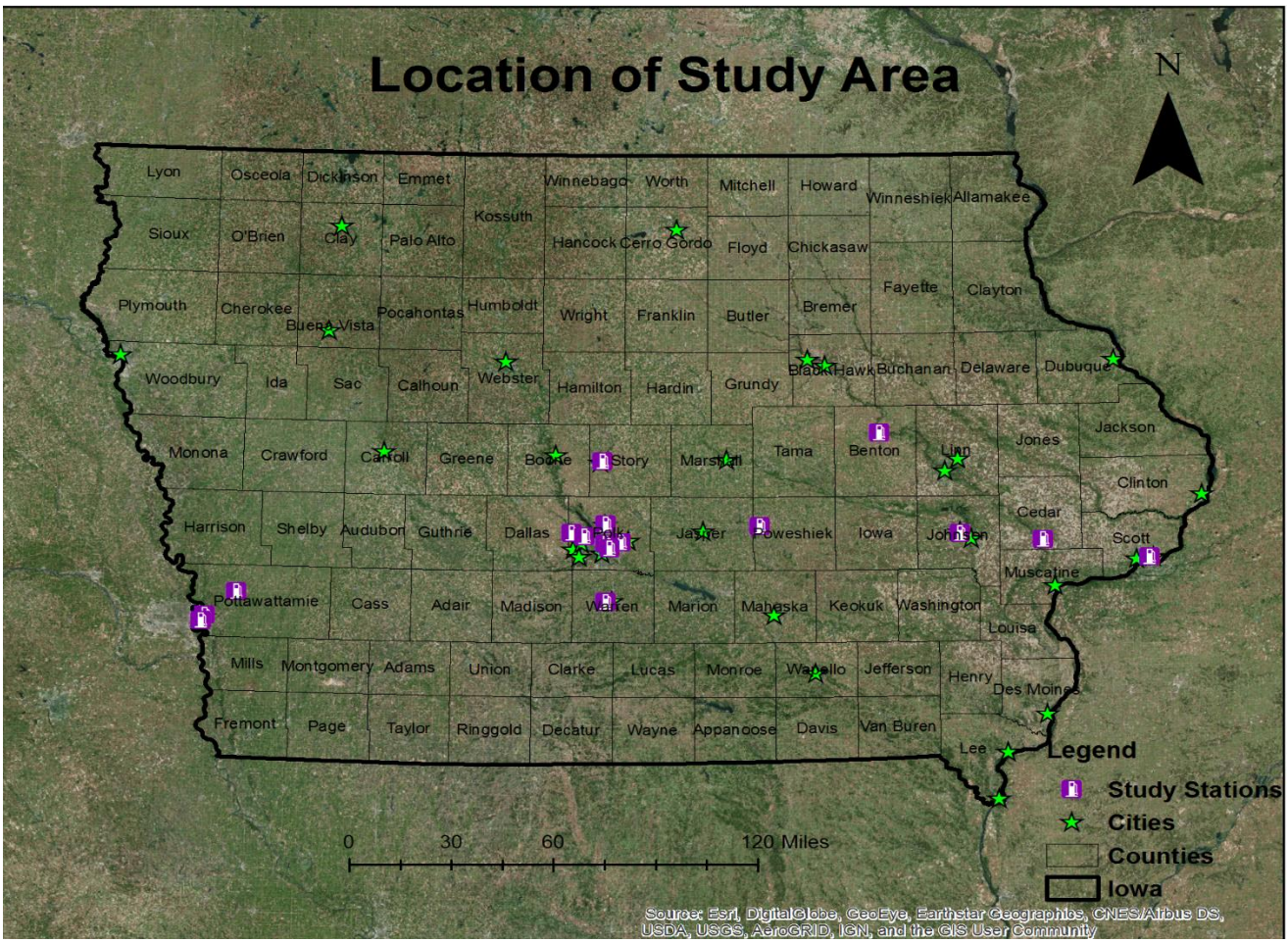

Figure 3-1 Study Locations in Iowa

Trained surveyors from the SRS Service performed the survey at the various gas stations across Iowa between September 2016 and August 2017. The surveys were presented to the customers by the surveyor as they fuel their vehicles. A total of 1464 response were collected.

3.2 Data Aggregation

The responses from the surveys were manually entered and coded using Microsoft Excel. The data were aggregated by station and summarize by topic. Additionally, the results were expressed based on the brand location rather than the individual location. The identity of stations regarding the results was coded as A, B, C, D, E, and F hereon forth in this paper. Table 3-1 below

shows a summary of the common responses for each station as it pertains to a few of the questions of the survey.

Table 3-1 Summary of Common Response

Question	**Common Response at Stations**					
	A	B	C	D	E	F
Fuel Purchased	E-10 (61%)	E-10 (53%)	E-10 (67%)	E-10 (39%)	E-10 (64%)	E-10 (38%)
Main Reason for buying this Fuel	Compatible (32%)	Cost (43%)	Cost (36%)	Compatible (60%)	Cost (44%)	Cost (50%)
Aware of different fuel blends available at station	Yes (66%)	Yes (71%)	Yes (70%)	Yes (83%)	Yes (76%)	Yes (63%)
Likeliness of Purchasing a vehicle designed to use higher blends of ethanol more efficiently	Somewhat Likely (33%)	Very Likely (36%)	Somewhat Likely (27%)	Very Likely (37%)	Somewhat Likely (27%)	Very Likely (50%)
Gender	Male 69%	Male 71%	Male 88%	Male 65%	Male 73%	Male 75%
Age	20-29 (22%)	40-49 (26%)	60-69 (33%)	50-59 (25%)	30-39 (23%)	20-29 (38%)
Income	Over $70k (44%)	Over $70k (37%)	From $30k to $70k (36%)	Over $70k (48%)	Over $70k (40%)	From $30k to $70k (38%)

Table 3-1 shows that the most common fuel purchase was E10 at all fuel stations. It is important to note that fuel type E10 is the limit for passenger vehicles which has a model year older than 2001, so it would be a common fuel to purchase in a sense of compatibility and availability. However, the compatibility is not the sole or common reason, but cost is also a factor. Moreover, the table shows that majority of respondents are aware of the different fuel-blends are available at the station they purchase their fuel. They are also open to purchase a vehicle that is more efficient to higher ethanol blend fuel if given a choice. For an unexplained reason, the sample

size included more males than females hence the results in the table. More detailed analysis and results are provided in Chapter 4.

3.3 Logistic Regression Model

The logistic regression model can measure the relationship between dependent variables or independent variables by estimating the probabilities using logistic functions. For logistic regression, a binary indicator variable coded as 1 or 0 in the case of this project, fuel purchased was transformed into a binary to be the dependent variable. E-0 to E-10 (lower blend) was coded grouped and coded as 0 while E-15 to E-85 (higher blend) was coded as 1. The purpose of the model was to determine what variables influences or increase the probability of a higher ethanol fuel blend.

A logistic regression model starts with a basic logic model which β_0 model constant, and β_1, where β_i are the unknown parameters corresponding to the explanatory variables.

Equation 3-1

$$y_i = logit\ (P_i) = \ln\left(\frac{P_i}{1 - P_i}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k$$

CHAPTER 4. RESULTS AND DISCUSSION

4.1 Survey Results & Relationships

Consumers were asked what type of fuel they were purchasing, which is illustrated in Figure 4-1 below. As seen, more than half of the respondents' fuel of choice was E-10, which satisfy what was shown in Table 3-1 as being a common fuel purchased. Also, it shows that majority (68%) of the respondents prefer ethanol blend fuel versus unleaded gasoline, E-0, (24%) when combined. Also, this collaborates with the fact that 85% of fuel sales statewide is E-10 based on the 2016 report by the Iowa Department of Revenue. It is important to note that in few cases the E-0 and E-10 is disperse from the same pump so some respondents may not be aware fuel they purchased. However, respondents who purchased E-10 or E-0 were also asked why they did not purchase a higher ethanol blend. About 36% stated that it was due to incompatibility, and 33% said other reasons such as price. Only 12% selected fuel mileage while 18% claim they did not know.

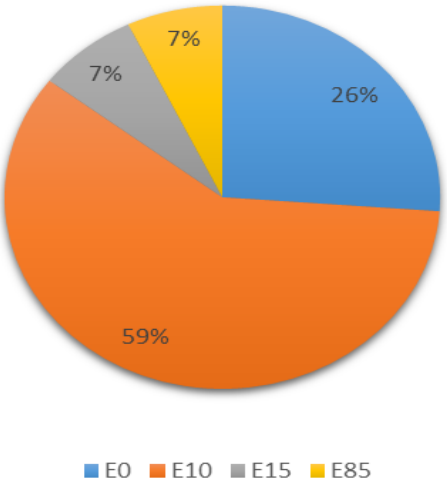

Figure 4-1 Type of Fuel Purchased

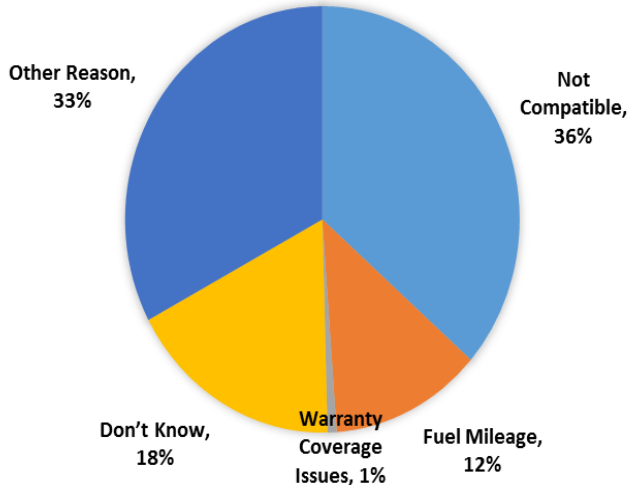

Figure 4-2 Reason for Not Purchasing Higher Ethanol Blend

The previous question was only asked to a subset of respondents based on their answers hence the need for further questioning on their reason behind their fuel choice. Illustrated in Figure 4-3 below, the top two reasons for purchasing a certain fuel type were cost (35%) and compatible fuel (38%). A few revealed that habit (15%) was their reason.

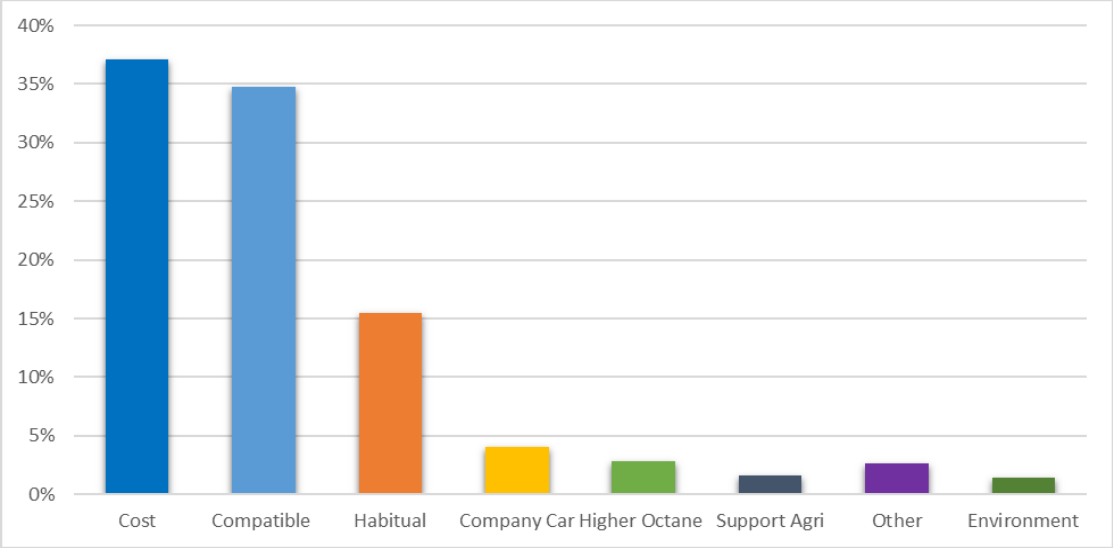

Figure 4-3 Primary Reason for Respondents Choice

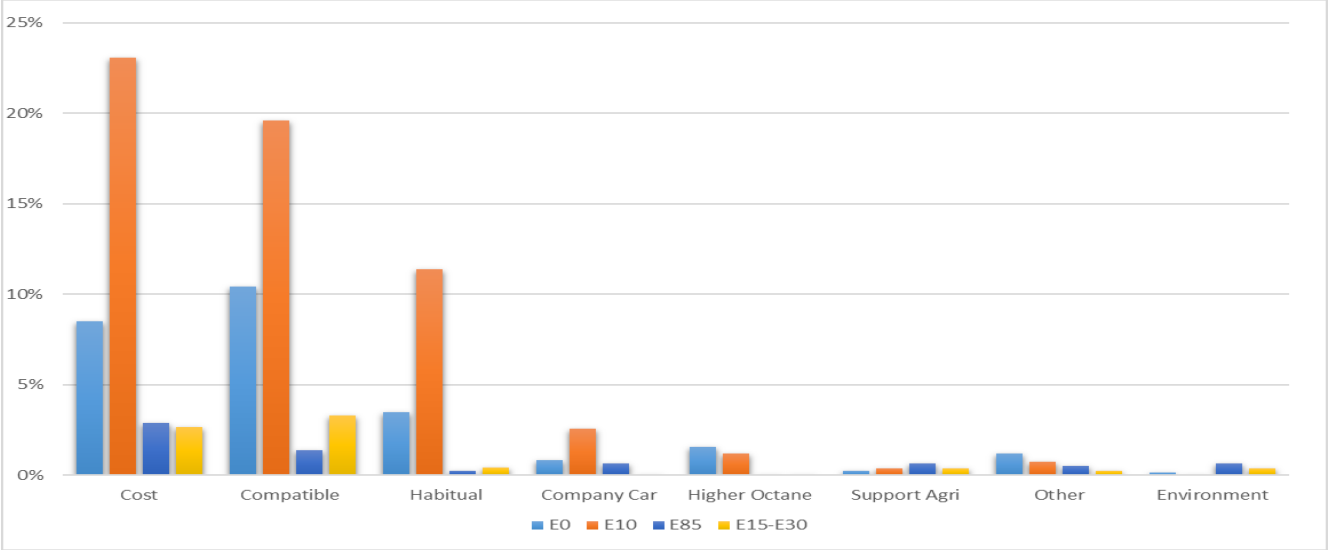

Figure 4-4 Breakdown of Reasoning by Fuel Type Purchased

Additionally, Figure 4-4 illustrates the breakdown of the fuel choice by type of fuel purchased. Most of the responders who selected either cost, compatibility or habit fuel of

choice is E-10. At the participating fuel stations, regular gasoline was more expensive than ethanol blend fuel, so it was very surprising that a high percentage of consumer who purchase E-0 listed cost as a major influence. However, cost was less of a factor for individuals who purchased higher blend of ethanol.

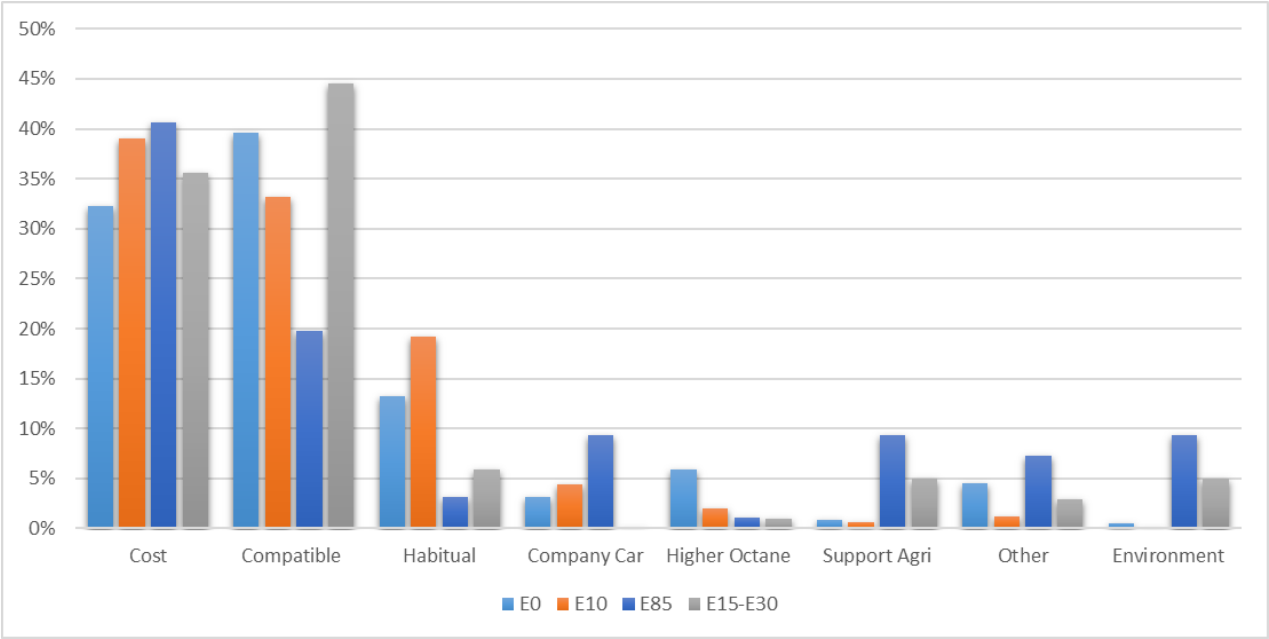

Figure 4-5 Relationship between Fuel Purchased and Respondents Reasoning

Figure 4-5 illustrates the percentage of the fuel type purchased selected a particular reasoning. For instances, 41% of the respondents who fuel choice was E-85 stated their reason to be cost. It is no surprise that those who fuel preference was E-85 stated the reason to be environmental reasons, 9%, as well as to support the agriculture industry, 9%. Also, respondents who purchased mid blend ethanol was mostly concerned with compatibility which is acceptable. 40% of respondents who purchase E-0 stated compatibility was their main issue.

To address to what extent cost was a factor in not purchasing E-85, respondents were asked whether they would reconsider their fuel choice to E-85 if the fuel they purchase was to increase by 25¢ increments. Based on Figure 4-6 below, most of the respondents would still

buy their fuel choice. However, there was slight decrease of respondents who answered no at the 50¢ and 75¢ increase but the 'don't know' response increased. So even though cost was an influential factor, respondents still seem reluctant to purchase higher ethanol blend, E-85 specifically. In some cases, vehicle compatibility was the main issue.

Figure 4-6 - Whether Respondent would buy E-85 if Fuel Bought Increased

Participating gas stations indicated that they were interested in gathering information about why customers choose their station, this is illustrated in Figure 4-7. 81% of the responders stated that the location of the station was very convenient. Eight percent stated other which includes the station having a loyalty or rewards program or the respondents has an account with that particular station. Figure 4-8 below illustrates that majority of the stations are in counties which have a medium size to small population. However, it is important to know that they have very close proximity to the highway system, which means that they are accessibly to both the local residents and individuals who are just passing through. This

correlates with the numerous response stating that the convenience of the station was their number one reason for selecting that gas station as seen in Figure 4-7.

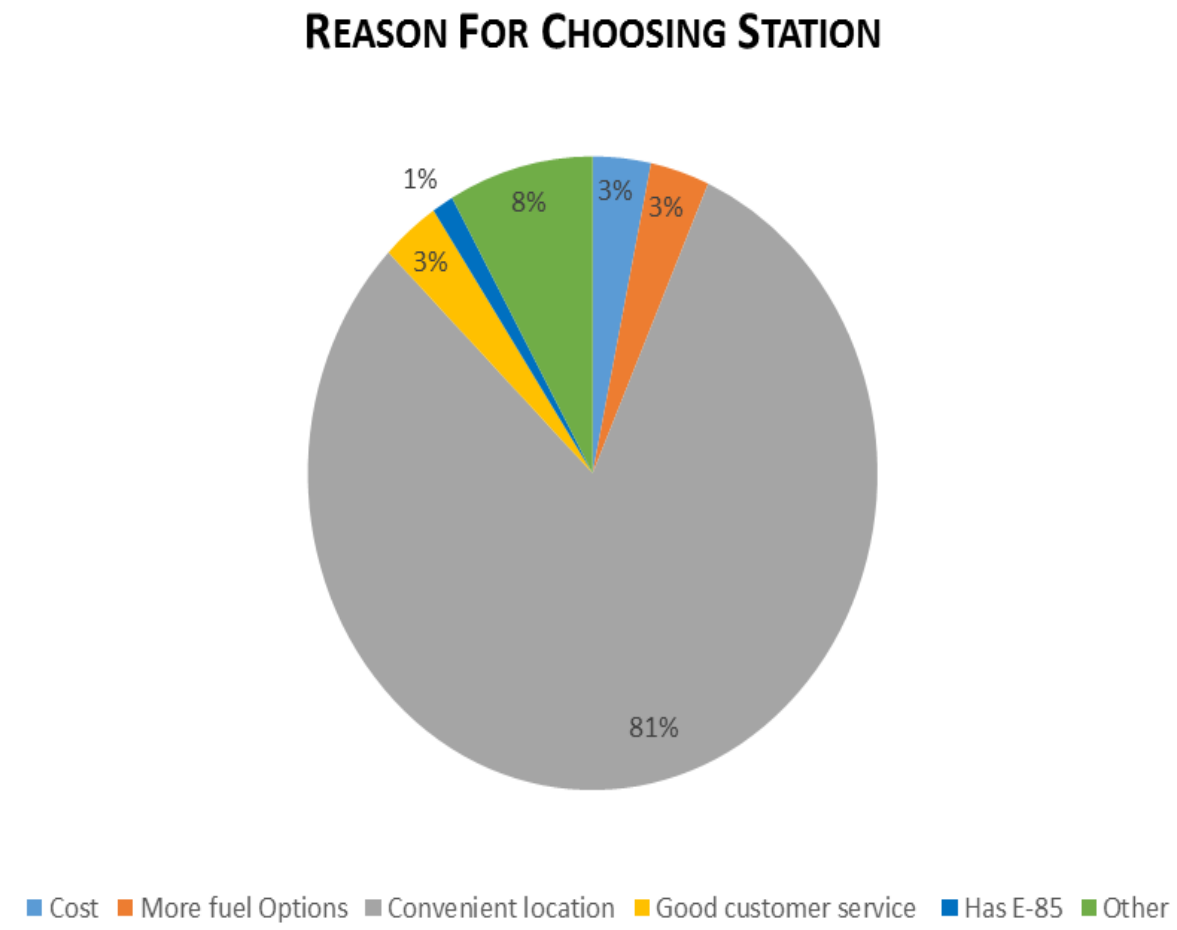

Figure 4-7 Reason for Selecting Fuel Station

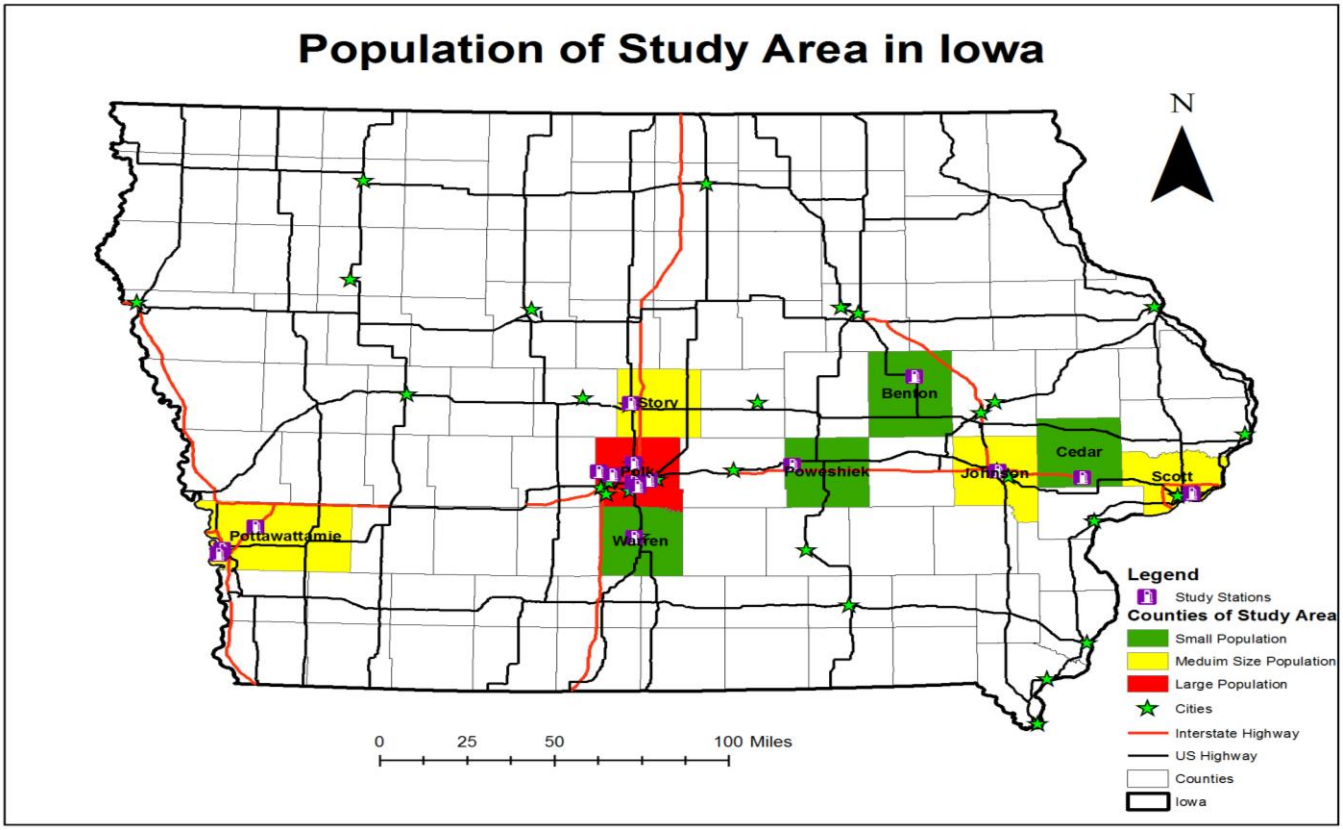

Figure 4-8 Population of the Study Area

Respondents were asked how likely they would to purchase a vehicle that can efficiently use higher blends of ethanol if such a vehicle was available. This is illustrated Figure 4-9 below. It is important to note that 31% of respondents indicated that they are somewhat likely to purchase a higher ethanol blend fuel efficient vehicle. In addition, 27% are very likely to buy a fuel-efficient vehicle and this indicates that respondents were educated and open to buying fuel efficient vehicles in Iowa as shown in Figure 4-9.

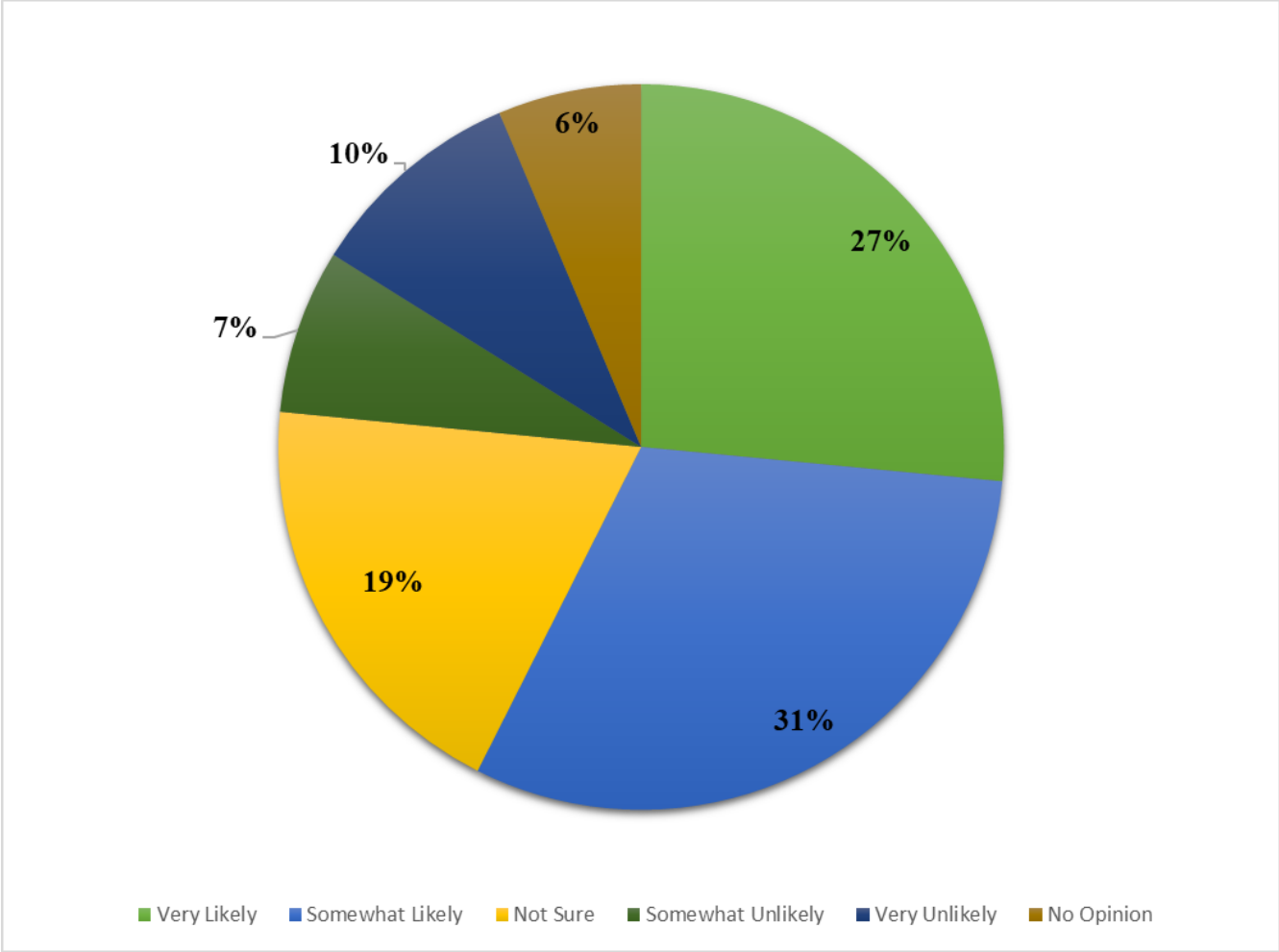

Figure 4-9: Likelihood of Purchasing a Fuel Efficient Vehicle

Surprisingly, respondents with lower income were more likely to purchase a higher ethanol blend fuel efficient vehicle based on Figure 4-10. Thirty percent of those making less than $30,000 and 33% of those making between $30,000 and $70,000 responded that they were very likely to purchase a fuel-efficient vehicle. In contrast, only 24 percent of respondents making more than $70,000 indicated that they were more likely to purchase a vehicle that can efficiently use higher blends of ethanol. It may be possible that people with lower income see an economic advantage in purchasing a vehicle that uses ethanol more efficiently because ethanol blends are cheaper than regular gasoline.

Figure 4-10: Income Impact on the Likelihood of Purchasing Fuel Efficient Vehicle

Even though most respondents with lower income indicated that they were more likely to purchase a vehicle that can efficiently use higher blend of ethanol, the average household within 1 mile of each gas station in Iowa is over $75,000 as shown in Figure 4-11.

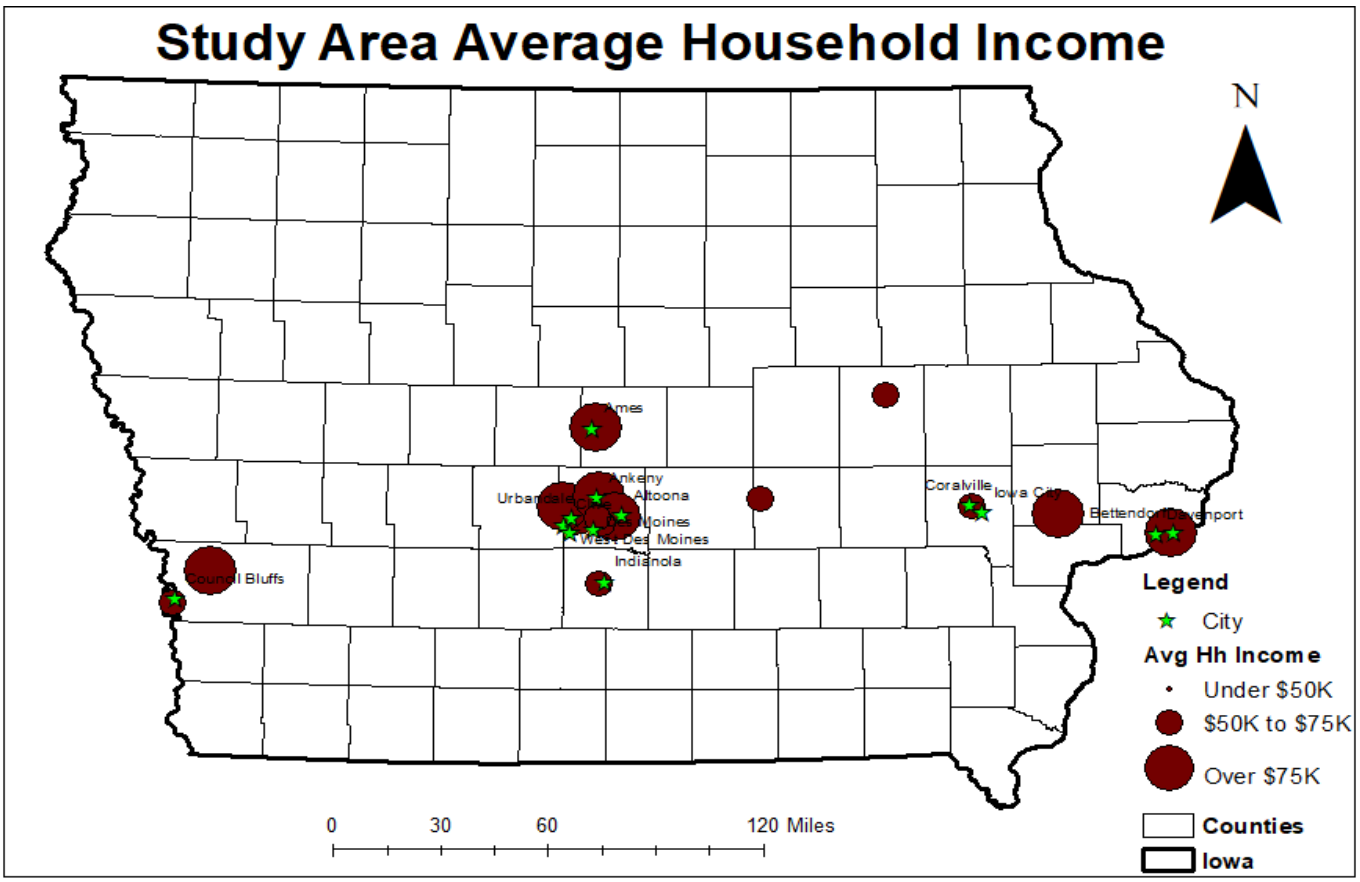

Figure 4-11: Average Household Income of Study Area

Table 4-1 below illustrate the percentage of each income categories of the sample versus the average percentage of the population in Iowa. This shows that survey captures a representative from each income.

Table 4-1: Average Household Income Sample versus Population

Income Range	Sample	Iowa
Under 30K	7%	26%
30K to 70K	34%	33%
Over 70K	58%	40%

To further understand consumers, it is important to note that 71 percent of respondents are male as shown in Figure 4-12. An odd ratio test was performed to compare the gender to evaluate the odds of purchasing a particular fuel using the following equation. 'PG_1' represents the odds of an event of interest for group 1, and 'PG_2' represents the odds of the event of interest for group 2.

Equation 4-1: Odds Ratio Formula

$$Odds\ Ratio: \frac{(\frac{PG_1}{1-PG_1})}{(\frac{PG_2}{1-PG_2})}$$

This was used to determine what are the odds a specify gender will purchased an ethanol blend fuel. Hence the fuel purchase by gender is illustrated in Figure 4-13 below. The figure shows that the female and male respondents gave very close responses but using the odd ratio females were 1.08 more likely to purchase ethanol blend fuel.

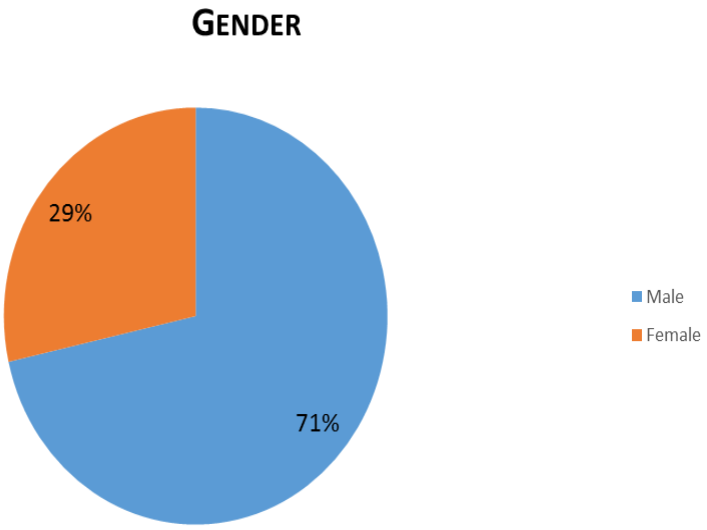

Figure 4-12: Gender of Respondents

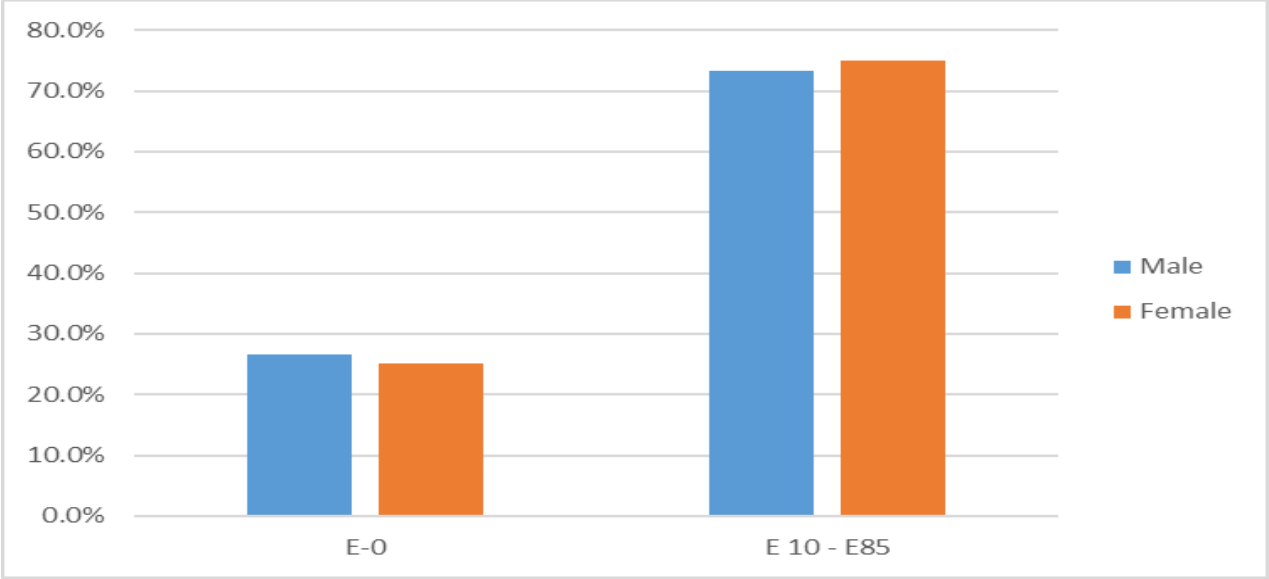

Figure 4-13: Gender Breakdown of Fuel Purchase

In Figure 4-14, age range 50 to 64 were accounted for the ethanol mid blend purchased. Also, E10 and E0 were popular among the younger adults. Using the odds ratio individuals were 1.45 more likely to purchase E10 than any other fuel. The age range was simplified to young (18 to 29), mid (30 – 49), and old (50 and above). Individuals who fell under the mid-range were 1.61 more likely to purchase E85 than the younger respondents. Also, the younger respondents were 1.03 and 1.10 more likely to purchase E10 than mid and older respondents respectively.

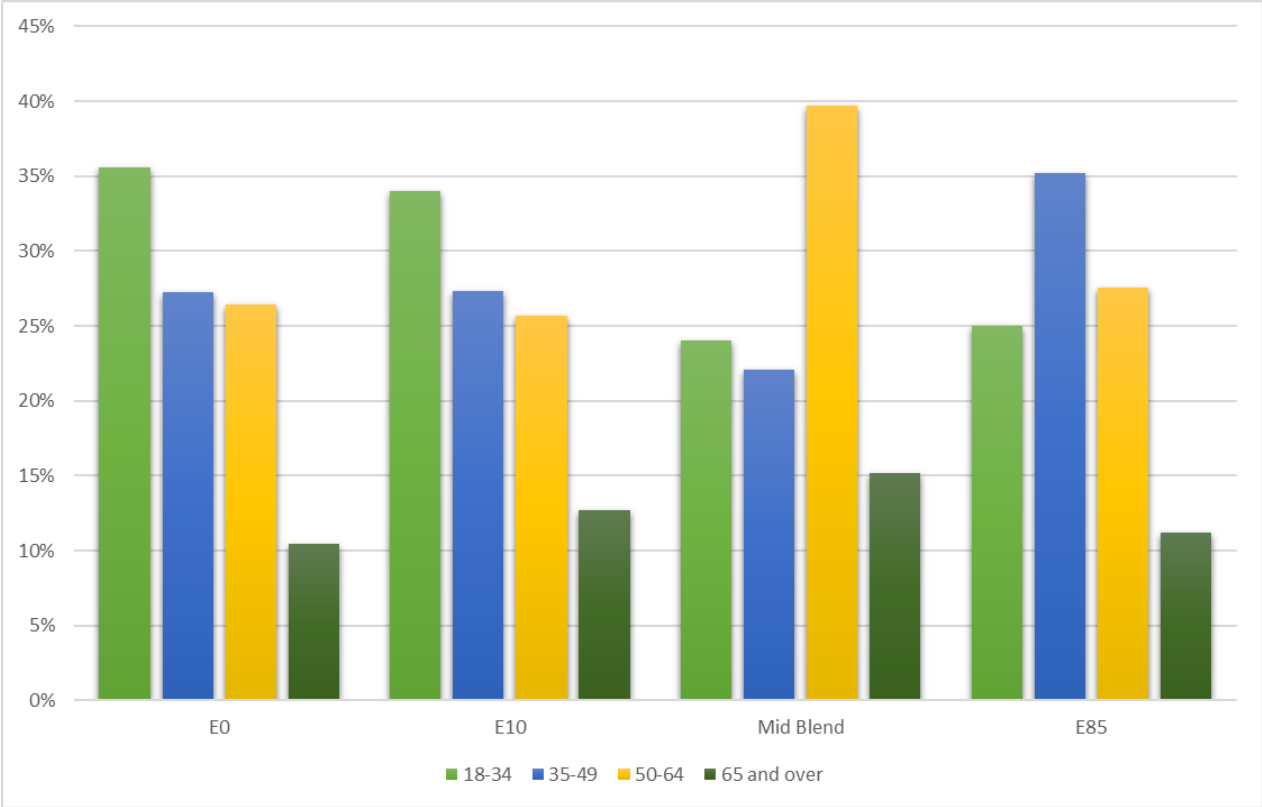

Figure 4-14: Age Impact on Fuel Purchase

4.2 Logistic Regression Model Results

The logistic regression model was used as the predictive model to determine which variables increase the probability to purchasing a higher ethanol fuel blend, E-15 to E=85. Table 4-2 below displays the results of the first model which considered all the data collected. In this model the habitual practice and environmental benefits reasoning were significant as well as fuel option available and convenient location of the fuel stations influences the probability of selecting a higher blend of ethanol fuel. Moreover, the respondents openness to purchasing a higher blend was also a factor as the model shows that the unlikely response to purchasing a vehicle that is more efficient to higher ethanol blend in the future was significant.

Table 4-2: Purchasing Higher Ethanol Fuel Blend Prediction Model

Term	Estimate	Std Error	Chi Square	Prob >Chi Sq
Intercept	0.908	0.250	13.23	**0.0003**
Main Reason for Fuel Choice				
Cost	0.147	0.237	0.38	0.5355
Environmental Benefits	-2.387	0.446	28.66	**<.0001**
Higher Octane	1.693	0.909	3.47	0.0626
Compatible	0.290	0.243	1.42	0.2336
Habitual Practice	1.263	0.369	11.71	**0.0006**
Company	0.483	0.463	1.09	0.2972
Purchase vehicle more efficient to higher blend of ethanol				
Likely	-0.265	0.155	2.94	0.0865
Not Sure	0.180	0.212	0.72	0.3957
Unlikely	0.579	0.240	5.83	**0.0158**
Reason for selecting particular fuel station				
Cost	0.370	0.365	1.03	0.311
Fuel Options	-1.505	0.290	26.97	**<.0001**
Convenient Location	0.837	0.186	20.2	**<.0001**
Good Customer Service	-0.068	0.378	0.03	0.8569

A second model was developed to look at vehicles who did not list compatibility as the issue to why they did not purchase a higher ethanol blend of fuel. Table 4-3 below displays the results which is similar to the previous model. However, in this model, the awareness of other fuel blends available at the respective station shows significances. As well as, regarding the openness to purchasing a vehicle that can efficiently use a higher ethanol blend fuel variable, both ends of the spectrum was significant, ‘likely’ and ‘unlikely’.

Table 4-3: Prediction Model of Compatible Vehicles

Term	Estimate	Std Error	Chi Square	Prob >Chi Sq
Intercept	0.940	0.2970677	10.01	**0.0016**
Main Reason for Fuel Choice				
Cost	0.184	0.258	0.51	0.477
Environmental	-2.311	0.502	21.21	**<.0001**
Higher Octane	1.751	0.977	3.21	0.0731
Compatible	0.021	0.284	0.01	0.9396
Habitual	1.320	0.401	10.83	**0.001**
Company	0.607	0.479	1.61	0.2051
Aware of different fuel blend available at station				
Yes	-0.299	0.134	4.93	**0.0264**
Purchase vehicle more efficient to higher blend of ethanol				
Likely	-0.377	0.184	4.2	**0.0405**
Not Sure	0.053	0.255	0.04	0.8362
Unlikely	0.759	0.300	6.41	**0.0114**
Reason for selecting particular fuel station				
Cost	0.806	0.435	3.43	0.0641
Fuel Options	-2.096	0.406	26.69	**<.0001**
Convenient Location	0.880	0.231	14.54	**0.0001**
Good Customer Service	-0.292	0.498	0.34	0.558

CHAPTER 5. CONCLUSION AND LIMITATIONS

5.1 Conclusion

In conclusion the choice of fuel among responders was E-10, followed by E-0. Additionally, both compatibility and cost mostly influenced consumers. However, even though cost was a factor, individuals still seem reluctant to purchase higher ethanol blend, E-85 specifically. This was revealed when asked if the price for lower blend ethanol (E-0 to E-15) is increased, majority of responders would still buy this type of fuel when compared to E-85. Also, the results showed that individuals had a higher income were not fully open to purchasing fuel efficient vehicle even though they are likely to be more educated and have more disposable income.

The models showed that environmental benefit and habitual practices for main reason for fuel choice, as well as the fuel options available and the convenient location to selecting a particular station were highly significant on probability to selecting a higher blend.

5.2 Limitation

Throughout the data collection there was always the possibility on whether respondents interpreted the questions correctly. Also, the zip code of the respondent could have been acquired to do additional analysis to determine whether the customers were commuters or locals as they listed the station to be in a convenient location. Moreover, it could have been used to determined whether are any clusters.

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APPENDIX A. SURVEY TEMPLATE

Iowa Driver Survey of Fuel Use

September 2016

1. What type of fuel are you buying today?

01 = Unleaded Gasoline
02 = E-10
03 = E-15
04 = E-20
05 = E-30
06 = E-85
10 = Number 2 Diesel
11 = Off-road diesel (Red Dyed) → **3. [IF Off-Road, ASK:] Is this fuel being used for farming, construction, a personal vehicle, or for something else?**
12 = Other fuel: _____

→ **2. What is your main reason for not purchasing a (higher) ethanol blend?**
1 = Not compatible with this vehicle, potential engine damage
2 = Fuel mileage – (higher) ethanol blends don't perform as well
3 = Warranty coverage issues
4 = Don't know
5 = Other reason: _____

1 = Farming
2 = Construction
3 = Personal vehicle
4 = Other: _____

4. What is your main reason for buying this type of fuel? *[Probe for one main reason; read options if helpful.]*

1 = Cost
2 = Environmental benefits
3 = Supports agriculture
4 = Higher octane fuel
5 = Compatible with vehicle, Works best in this vehicle
6 = Habitual, Always buy it, No reason
7 = Reduce dependence on foreign oil
8 = Required by employer (company car)
9 = Other:

*[ASK Q5 & Q6 ONLY AT **E-85 STATIONS**.]*

[IF BOUGHT UNLEADED, E10 OR E15, ASK:]

5. E-85 is $_____.

If the fuel you bought today was:			Yes	No	DK
a. (+.25)	$	…would you consider buying E-85 instead?	1	2	3
b. (+.50)	$		1	2	3
c. (+.75)	$		1	2	3

[IF BOUGHT E-85, ASK:]

E-85 is $_____.

Would you still buy E-85 if it cost:			Yes	No	DK
a. (+.25)	$	?	1	2	3
b. (+.50)	$	?	1	2	3
c. (+.75)	$	?	1	2	3

7. Are you aware of the different fuel blends and options available at this station?
[Can probe whether they noticed the yellow/blue pumps.]

1 = Yes
2 = No
3 = Not sure

8. If you were buying a car, how likely would you be to purchase a vehicle designed to more efficiently use higher blends of ethanol? Would you say . . .

1 = Very likely,
2 = Somewhat likely,
3 = Not sure,
4 = Somewhat unlikely or
5 = Very unlikely?
6 = REFUSE, NO OPINION

9. Why do you buy gas at this particular station? *[Circle all that apply]*

1 = Cost
2 = More/Good fuel options
3 = Convenient location
4 = Good customer service
5 = Has E-85
6 = Other: _____

10. What is the year, make, and model of this vehicle? Is it a Flex-Fuel vehicle?

[Circle vehicle type]	Year	Make	Model	Is it Flex-Fuel?
1 = Passenger car 2 = Motorcycle 3 = Van, SUV, Pickup 4 = Large truck 5 = Ag vehicle/equipment 6 = Other _____				1 = Yes 2 = No 3 = Unsure

11. Finally, I have a couple of background questions about you.

[Record Gender]	What is your age category?	Is your household's yearly income . . .
1 = Male 2 = Female	1 = 18 or 19 2 = 20 – 29 3 = 30 – 39 4 = 40 – 49 5 = 50 – 59 6 = 60 – 69 7 = 70 and above	1 = Under $30,000 2 = From $30,000 to $70,000 or 3 = Over $70,000? 4 = Don't Know, prefer not to answer

That's all the information we need. Iowa State University and the Iowa Department of Transportation thank you for your time today.

APPENDIX B. IRB APPROVAL MEMO

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
2420 Lincoln Way, Suite 202
Ames, Iowa 50014
515 294-4566

Date: 8/10/2016

To: Dr. Shauna Hallmark
2711 S Loop Dr, Suite 4700

From: Office for Responsible Research

Title: Evaluation of Fueling Our Future – Phase II

IRB ID: 16-282

Study Review Date: 8/10/2016

The project referenced above has been declared exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b) because it meets the following federal requirements for exemption:

- (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey or interview procedures with adults or observation of public behavior where
  - Information obtained is recorded in such a manner that human subjects cannot be identified directly or through identifiers linked to the subjects; or
  - Any disclosure of the human subjects' responses outside the research could not reasonably place the subject at risk of criminal or civil liability or be damaging to their financial standing, employability, or reputation.

The determination of exemption means that:

- **You do not need to submit an application for annual continuing review.**
- **You must carry out the research as described in the IRB application.** Review by IRB staff is required prior to implementing modifications that may change the exempt status of the research. In general, review is required for any modifications to the research procedures (e.g., method of data collection, nature or scope of information to be collected, changes in confidentiality measures, etc.), modifications that result in the inclusion of participants from vulnerable populations, and/or any change that may increase the risk or discomfort to participants. Changes to key personnel must also be approved. The purpose of review is to determine if the project still meets the federal criteria for exemption.

  Non-exempt research is subject to many regulatory requirements that must be addressed prior to implementation of the study. Conducting non-exempt research without IRB review and approval may constitute non-compliance with federal regulations and/or academic misconduct according to ISU policy.

  Detailed information about requirements for submission of modifications can be found on the Exempt Study Modification Form. A Personnel Change Form may be submitted when the only modification involves changes in study staff. If it is determined that exemption is no longer warranted, then an Application for Approval of Research Involving Humans Form will need to be submitted and approved before proceeding with data collection.

Please note that you must submit all research involving human participants for review. **Only the IRB or designees may make the determination of exemption**, even if you conduct a study in the future that is exactly like this study.

Please be aware that **approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **An IRB determination of exemption in no way implies or guarantees that permission from these other entities will be granted.**

Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.