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16. Abstract

The fuel tax, which is assessed on the physical amount of fuel purchased by the consumer, is the primary means of funding roadway development at the state and national level. However, because it is assessed on a gallon basis, drivers of vehicles with a low fuel efficiency pay more per mile for use of the roadway than drivers of more fuel efficient vehicles. If there is a relationship between fuel efficiency and income, such that lower income drivers are more likely to drive a low fuel efficiency vehicle, then the equity of the fuel tax is in question. In this study, researchers analyzed over 350,000 vehicle registration records from around the State of Texas to determine if areas with a lower median income had a higher distribution of low fuel efficiency vehicles. Researchers found that vehicles registered in lower income areas tended to have lower average fuel efficiencies than vehicles registered in areas with mid-range and higher income. Lower income areas and rural areas were also more likely to have a higher percentage of class 35 vehicle registrations, usually larger light duty pickup trucks and sport utility vehicles, which tend to have lower fuel efficiency.

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THE RELATIONSHIP BETWEEN INCOME AND PERSONAL VEHICLE FUEL EFFICIENCY AND ASSOCIATED EQUITY CONCERNS FOR THE FUEL TAX

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And Associated Equity Concerns for the Fuel Tax

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DISCLAIMER

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EXECUTIVE SUMMARY

Fuel taxes, which are levied on a per gallon basis, make up the largest share of funding for roadway infrastructure. In Texas revenues from state and federal fuel taxes account for over 80 percent of funds placed in the State Highway Fund.

Fuel taxes by their nature are not the most equitable tax. Unlike income taxes, which are considered vertically equitable, fuel taxes do not vary based on the income of the person paying them. Low income drivers pay the same per gallon rate for fuel as higher income drivers. Furthermore, fuel tax rates paid per mile driven vary based on the fuel efficiency of the vehicle. A vehicle with a very high fuel efficiency burns less gas and thus pays less in fuel taxes relative to a vehicle with low fuel efficiency. If two vehicles drive the same distance at the same time, the vehicle with the lower fuel efficiency will pay more for use of the same stretch of road. This relationship becomes problematic if low income drivers are more likely to drive inefficient vehicles.

In this research effort researchers analyzed over 350,000 vehicle registration records in order to determine if areas of the state with a lower median income were more likely to have a higher percentage of inefficient vehicles. Researchers used zip codes as the geographical unit of analysis, as it would allow for a better analysis of differences between urban and rural areas. Zip codes were selected from around the state in order to ensure that the sample was adequately representative of the state, and census data related to income were utilized to identify low, medium, and high income zip codes.

The analysis showed that lower income zip codes as a group had slightly lower average vehicular fuel efficiency than medium and high income zip code groups. Medium income zip codes tended to have the highest average fuel efficiency. Upon further analysis, it was found that the lower income zip codes, as well as zip codes in rural areas, also had a higher percentage of class 35 vehicles, which may account for the lower average vehicular fuel efficiencies. In state vehicle registration records, class 35 is generally comprised of heavier vehicles such as pickup trucks and sport utility vehicles.

INTRODUCTION

Taxes on petroleum products such as gasoline and diesel (“fuel taxes”) are excise taxes in that they are levied on the physical amount of fuel purchased as opposed to the purchase price. While there are currently several states that do levy a sales tax on the purchase price of gasoline (California, Connecticut, Delaware, Georgia, Hawaii, Illinois, Indiana, Michigan, New Jersey New York, and Ohio) most states levy a per gallon excise on fuel purchased for personal use. Some states also levy similar taxes on the liquefied petroleum gas (LPG), liquefied natural gas (LNG), and compressed natural gas (CNG), but these are also in the form of an excise on the physical amount purchased.

Fuel taxes were initially implemented by the State of Oregon at a rate of 1 cent per gallon. Their initial purpose was to generate usage-based revenues for the state. Fuel taxes can be thought of as a user fee because at the time they were initially implemented, as it is still the general case today, most vehicles would be unable to use the roadway system without first purchasing the taxed fuel. In the decades following Oregon’s lead, fuel taxes became much more popular as a means of generating revenue for the development of the nation’s burgeoning roadway network, and within 10 years all 48 of the contiguous United States had implemented fuel taxes. By the early 1930s, and in direct response to pressures on federal revenue sources due to the Great Depression, the federal government itself levied a fuel tax (*1*).

Since that time, fuel taxes have provided the bulk of funding for the development of state and national infrastructure. In addition to roadway development, federal fuel taxes provide a significant amount funding for transit, rail, and waterways. In Texas, it is estimated that in 2008 and 2009 that state and federal gasoline and diesel fuel tax revenues accounted for 32 percent and 49 percent of State Highway Fund revenues, respectively (Figure 1) (*2*).

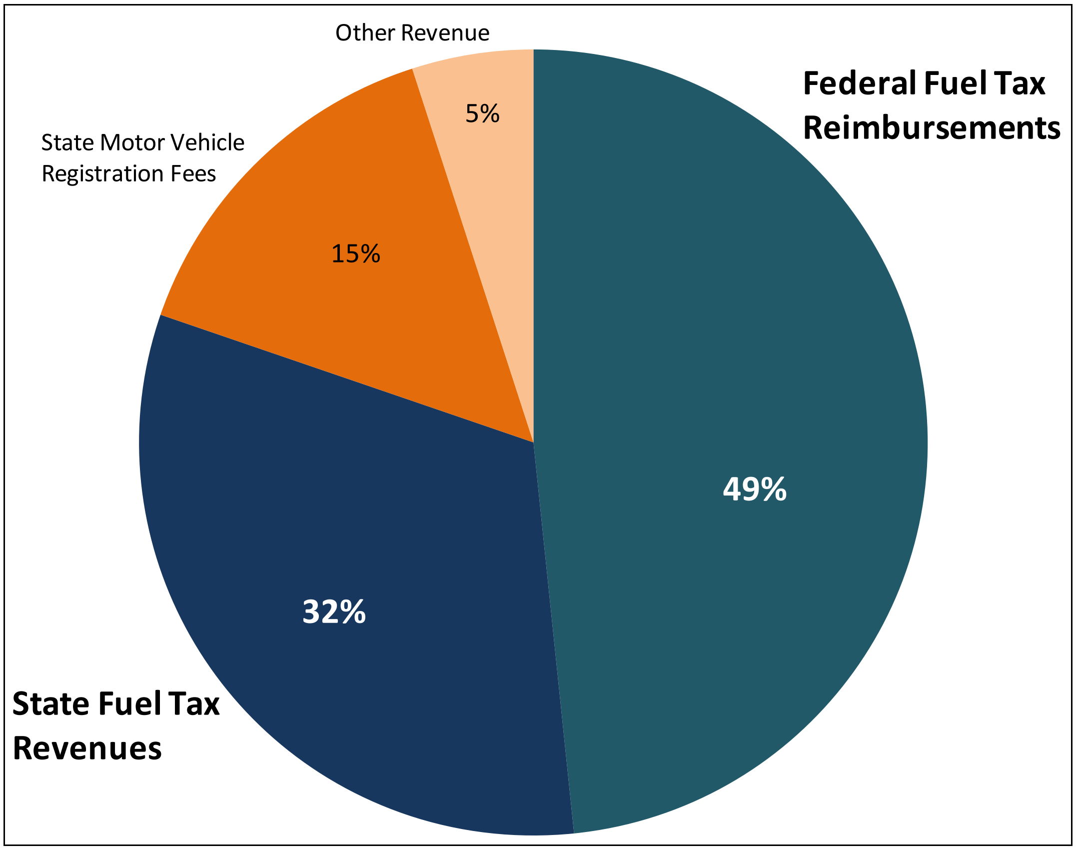


Figure 1: Sources of State Highway Fund Revenue, 2008–2009

The federal fuel tax is 18.4 cents per gallon for gasoline and 24.4 cents for diesel fuel. In Texas the fuel tax is 20 cents for both gasoline and diesel fuel and has been held at that rate since 1991. These taxes are paid at the pump by purchasers of fuel but they are a reimbursement to fuel suppliers and distributors. Fuel taxes are, in general, assessed and paid at the point where fuel is originally purchased by a wholesale fuel supplier. While not all taxes on liquefied petroleum fuels are assessed in this manner (blended fuels for example, are removed from the bulk transfer system but not by a supplier and not for sale) most are. As such, each holder of the fuel reimburses the entity that possessed it until the tax is eventually paid by the consumer.

Fuel taxes are only assessed for fuel used for personal and commercial uses and are meant to act as a user fee for those using the roadway network. As such, there many uses of fuel that are exempt from either state or federal fuel taxes. These include:

- Non-highway uses, such as for agricultural purposes.
- Fuel used by public school systems.
- Fuel used for aviation.
- Fuel used by public transit authorities.

While fuels purchased for these uses may still be subject to taxes at the point of sale, the purchasers are generally provided with opportunities to file for refunds if they have proper documentation.

THE EQUITY ISSUE

Equity (or fairness) deals with the actual (and perceived) costs and benefits that accrue to different segments of society. These segments are most often classified by income, location of residence, or minority status, but there are other social categorizations that might fill various definitions of equity such as geographic and generational equity. For the purposes of this research, equity will be examined from the perspective of income equity. Furthermore, while there are numerous other measures that can (and should) be taken into account when evaluating taxing mechanisms (such as efficiency, simplicity, and sustainability) this research effort will focus primarily on the issue of equity.

When evaluating equity, there are two primary competing principles that should be examined (*3*):

- The "*benefits*" principle – states that those who pay a tax should be those that benefit from the public goods and/or services that are received.
- The "*ability to pay*" principle – states that consumers of governmental goods and services should pay according their ability to pay, with lower income individuals paying less relative to those with higher income.

The ability to pay principle is compounded by the concepts of "vertical" and "horizontal" equity. Horizontal equity refers to the notion that those with equal ability to pay should pay equally. In terms of looking at income related issues, horizontal equity would dictate that those with equal income should pay the same amount. Federal income taxes, for example, are often attacked on horizontal equity grounds because the various exemptions provided mean that individuals with equal income will pay different amount due to home ownership or the presence of dependent children. Vertical equity refers to the notion that those with more of ability to pay (i.e., higher income) should pay more. As such, income taxes are generally regarded as vertically equitable because those with higher incomes are subject to a higher tax bracket.

These various notions of equity are obviously in conflict with one another, and there is no hard guidance on which principles and conceptions should prevail. Ultimately, the desired equity of a tax is subject to legislative and other political prerogatives.

Fuel Taxes and Equity – Broad Assessment

Excise taxes in theory are among the most equitable in terms of the *benefits* principle. Consumers of the good receive benefits in proportion to what they are paying. While fuel taxes are indeed an excise tax, the commodity from which consumers receive benefit (road use) is less and less connected with payment of the tax. Under a truly equitable excise tax (in terms of the benefits principle), the benefit received (in terms of road use) for payment of the fee would be equal for all consumers that pay an equal amount. However, this is simply not the case.

The fuel tax is only a proxy for use of the roadway network. It is a tax on the consumption of fuel, which is not a direct charge on the use of roadway resources. Depending on the fuel efficiency of the vehicle being driven, certain drivers will receive more "use" and benefit from the roadway network than the drivers of less fuel efficient vehicles (Figure 2).

Fuel Efficiency (Miles per Gallon)	State Fuel Taxes per mile driven	Federal Fuel Taxes paid per mile Driven
10	2.0 ¢	1.8 ¢
15	1.3 ¢	1.2 ¢
21	1.0 ¢	0.9 ¢
25	0.8 ¢	0.7 ¢
30	0.7 ¢	0.6 ¢
35	0.6 ¢	0.5 ¢
40	0.5 ¢	0.5 ¢
45	0.4 ¢	0.4 ¢

Figure 2: State and Federal Fuel Taxes Paid per Mile Driven Based on Fuel Efficiency

In terms of assessing fuel taxes based on the *ability to pay* principle and specifically horizontal equity, fuel taxes are for the most part equitable. This is due to the fact that drivers of equal income are not restrained from making certain vehicle purchases. Drivers of equal income are free and able to purchase the same vehicles and thus any horizontal inequity that may arise as a result of paying fuel taxes is a result of individual decision made by the driver. However, in terms of vertical equity, fuel taxes are in general not equitable. Fuel tax rates do not adjust based on the income of the fuel purchaser. The taxes levied per gallon of gas are equal for all users.

This vertical inequity is compounded by potential inequity resulting from an assessment based on the *benefits* principle. If low income drivers are less able to afford the purchase of more fuel efficient vehicles, then they are more likely to be paying more (in terms of fuel taxes paid per mile driven) for the benefit of utilizing the roadway network relative to higher income travelers who have more fuel efficient vehicles. This is compounded by the established vertical inequity of excise taxes and fuel taxes specifically.

The essential question that this research endeavored to examine is: to what extent is the fuel efficiency of personal vehicle ownership related to income?

Fuel Taxes and Equity – Other Research

Poterba (1990) examined the regressiveness of fuel taxes by examining expenditure patterns of low income drivers relative to higher income drivers. Traditionally, studies examining the regressivity of fuel taxes did so through the analysis of surveys of consumer income, which generally show that gasoline expenditures (and thus fuel tax expenditures) are a larger percentage of income for lower income households as opposed to middle or high-income households. Poterba argued that a better metric would be to utilize annual expenditures, which would provide “a more reliable indicator of household well-being than annual income.” Poterba utilized data from the Consumer Expenditure Survey to estimate the total share of expenditures that high-spending and low-spending (as opposed to high income and low income) households devote to retail gasoline purchases. According to this alternative method, it was concluded that low-expenditure households devoted a smaller share of their overall budget to gasoline and fuel taxes than their higher spending counterparts. Although households in the top 5 percent of spenders allocated less in gasoline purchases than those who spent less, the share of expenditures "devoted to gasoline is much more stable across the population than the ratio of gasoline outlays to current income." In other words, while the conventional wisdom that higher spending consumers do indeed spend less as a percentage of total expenditures on fuel than lower level spenders, there was little variation in spending on fuel among the bottom 95 percent of spenders. It was thus concluded that the gasoline tax "appears far less regressive than conventional analysis suggest" (*4*).

West (2001) similarly argues that expenditures are a better measurement of lifetime income and should be used in the analysis of how regressive fuel taxes are. The analysis utilized emissions data from the California Air Resources Board and household vehicle and income data from the US Consumer Expenditure Survey. West noted that lower income vehicle owners expend more on a per mile basis in proportion to their income, and that they are likely to drive vehicles that pollute more per mile. Thus, incidence of fuel taxes falls more heavily on these drivers. However, as West concluded, this burden "is mitigated to some extent by low vehicle ownership rates and high price responsiveness in the lower half of the income distribution." In other words, lower income drivers are less likely to own vehicles and, if taken as a whole, are less burdened by fuel taxes as a percentage of the total population. Furthermore, lower income drivers are much more likely to adjust their travel behaviors in response to higher prices; driving less or taking alternate means as opposed to expending more on fuel purchases (*5*).

These studies have illustrated that when taken as a whole, low income individuals (and not just low income drivers) are not disproportionately burdened by fuel taxes. However, for this research effort, the determination of equity and regressiveness will be determined for low income drivers and not low income individuals as a whole. The justification for this line of analysis is rooted in the *benefits* principle of equity, in that the analysis will examine potential disparities among groups of users who pay for and benefit from the roadway network. However, a case can be made for the assertion that all individuals, regardless of vehicle ownership, benefit in some way from the roadway network.

RESEARCH STRUCTURE AND METHODOLOGY

The question of how to evaluate the fuel tax in terms of equity for this research effort was a difficult one. Initially, it was the opinion of researchers that the preferred method for conducting this analysis would be to conduct a random survey of drivers in Texas and obtain information about their income, expenditures, and the fuel efficiency of the vehicles they drive. Given the expense of such an effort it was decided that an analysis of various state records would be more efficient. Furthermore, it was believed that most drivers would not be able to accurately determine their estimated fuel efficiency. However, as part of this effort protocols have been developed that, in the future, will allow researchers to calculate estimated fuel efficiency based on model, make, and year. This was a secondary objective of the research effort: to develop a tool that would allow the State of Texas to more accurately estimate the average fuel efficiency of the state registered auto fleet.

Researchers decided to utilize state vehicle registration records from the Texas Department of Motor Vehicles (TDMV) in the course of this research effort. Individual vehicle registration would be obtained and, based on the vehicle specific data contained within each record, an estimated vehicle fuel efficiency would be assigned for each record. These data would be aggregated and analyzed based on region, with the distribution of fuel efficiencies within each region providing the platform for determining if a relationship exists between fuel efficiency and income.

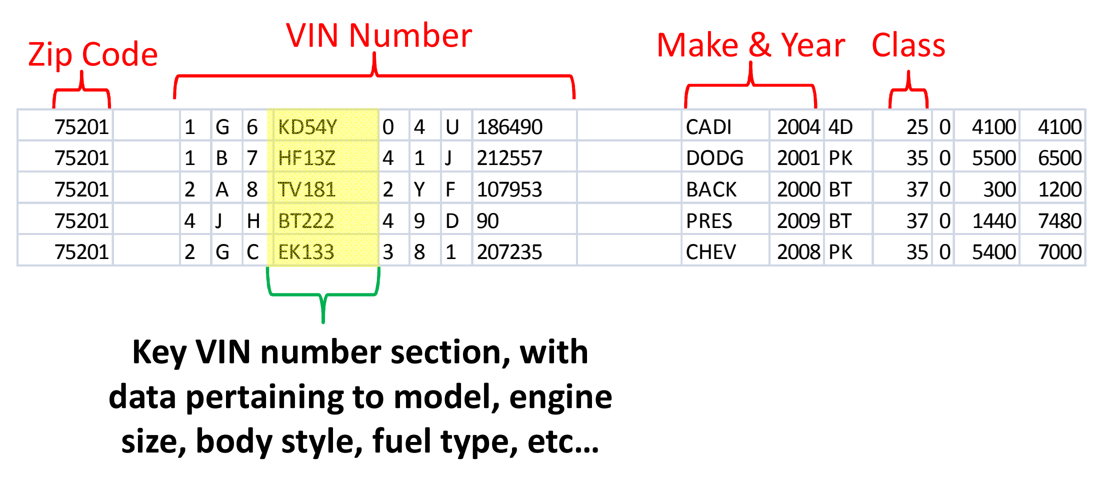
In addition to fuel efficiency, another item not contained within state vehicle registration records is any data pertaining to the income of the driver the vehicle is registered to. It was decided, therefore, that the geographic identifiers related to the data request to TDMV would have to be based on income. Furthermore, researchers wanted to be able to make distinctions in registrations made in large urban, mid-sized urban, small urban and rural areas. Researchers also wanted to ensure good regional representation in terms of the data set. As such, researchers decided that zip codes would form the geographic base upon which this analysis would occur, as zip code specific income data are provided by the US Census Bureau.

While the primary focus of the data gathering effort was to examine vehicle registration records to make observations about fuel tax equity, a secondary intention of researchers was to develop a framework for analysis of vehicle registrations that could be utilized by state agencies in the future. Many data sources utilized for the purposes of estimating and projecting revenues at the state level are based on sampling of the vehicle fleet. Researchers hoped that through this effort a system could be developed that would allow for state entities to input actual vehicle registrations for a given area of the state (or the state as a whole) and accurately determine the fuel efficiency characteristics for that area. This would allow for a more accurate projection of future fuel tax revenues in the long term and would allow for a detailed analysis of long term changes in fuel efficiency trends.

Researchers requested information from the TDMV for all vehicle registrations over a 1 month period for 30 zip codes. A summary of the zip codes and associated geographic and income information for each is provided in the Appendix. After data preparation, which will be discussed in the next section, there were a total of 355,038 vehicle registration records.

VEHICLE REGISTRATION DATA AND DATA PREPARATION

The vehicle registration records provided by the TDMV contained several bits of information (Figure 3). Each record contained the zip code the vehicle was registered in, vehicle manufacturer, year, vehicle class, and vehicle identification number (VIN).



75201		1	G	6	KD54Y	0	4	U	186490		CADI	2004	4D	25	0	4100	4100
75201		1	B	7	HF13Z	4	1	J	212557		DODG	2001	PK	35	0	5500	6500
75201		2	A	8	TV181	2	Y	F	107953		BACK	2000	BT	37	0	300	1200
75201		4	J	H	BT222	4	9	D	90		PRES	2009	BT	37	0	1440	7480
75201		2	G	C	EK133	3	8	1	207235		CHEV	2008	PK	35	0	5400	7000

Figure 3: Vehicle Registration Data Format

Vehicle Identification Number

As can be seen above, individual registrations did not contain any information related to the specific model of the car. Vehicle Identification Numbers (VIN) contained within each record served to identify specific vehicle models within their make classification. The number of digits contained within each VIN varies based on numerous factors, but for all VIN the 4th through 8th digits generally identify the model. The specific pattern with regards to which digits contain which model information varies depending on the manufacturer. Thus, "VIN Guides," as provided by vehicle manufacturers, were used to decipher this specific information.

For example, the 2010 VIN guide for Ford shows that digits 5, 6, and 7 determine the vehicle model. For all 2010 Ford vehicles, any registration with a "P7" as the 5th and 6th digit is a Crown Victoria. The 7th digit differentiates between various features of the Crown Victoria model. Microsoft Excel® and Microsoft Access® were used in the process of assigning model designation based on VIN.

In certain cases, vehicle manufacturers did not provide comprehensive VIN catalogue. In these cases, VIN patterns were found on non-manufacturer sites, such as the Association of International Automobile Manufacturers (AIAM). AIAM has published VIN guides for most non-American manufactured vehicles for the years 2003 through 2010.

Between these sources, a large portion of the registrations were successfully converted. For those that could not be derived from the online sources, estimation was used. In some cases, estimation was merely needed to cover a few model years. For instance, multi-purpose vehicles (trucks, SUVs, etc.) manufactured by Ford prior to 2000 were not found in any of these sources. In order to derive a model, researchers utilized various patterns present on more recent models and applied them to the older models.

For remaining vehicles, for which we had no information on manufacturer patterns, a manual VIN decoder was used. This step was rather slow and tedious, and therefore was reserved only for registrations on which no estimate could be made. VIN decoders are websites that a user manually enters the VIN, and the year, make, and model are displayed. The model information was then applied to all other registrations that shared the same manufacturer, year model, and 4th–8th digits of the VIN.

Vehicle Class

In Texas vehicle registration records, vehicles are assigned a 2-digit identifier that denotes special characteristics of the vehicle. Most vehicles fall within one of four classification categories:

- Class 25: Passenger Vehicle less than or equivalent to 6,000 lb.
- Class 26: Passenger Vehicle greater than 6,000 lb.
- Class 35: Truck less than or equivalent to 1 ton.
- Class 36: Truck greater than 1 ton.

Researchers believed that vehicle classification might be a variable worth examining with regards to fuel efficiency, especially with regards to class 25 and class 35 vehicles, which compose most of the standard passenger vehicle and light duty truck (respectively) fleet. However, the sample required significant cleaning with regards to this variable. For example, vehicles that would normally be classified as a class 25 or 35 might be given a different identifier based on various factors. For example, 2-digit identifiers are used in vehicle registrations to identify:

- Disabled veterans.
- Farm vehicles less than 1 ton.
- Purple Heart and Silver Star recipients.
- Active duty military personnel.

As such, all vehicle registration records that were not classified as a class 25, 26, 35, or 36 had to be examined individually in order to determine whether the vehicle would normally have been classified as one of the aforementioned categories.

First, all vehicle classifications that apply to non-passenger vehicles and non-light duty trucks were removed from the data set. These include:

- Motorcycles.
- Golf carts.
- Farm trailers.

- Travel trailers.
- Buses.
- Commercial vehicles.

The remaining records were next sorted in Microsoft Excel and Microsoft Access by make and model. Records containing a vehicle classification that was not a 25, 26, 35, or 36 were compared to records with a similar make, model, and year. In many cases, vehicle classification was not consistent within make, model, and year, particularly with regards to sport utility vehicles (SUV) such as the Chevrolet Suburban and the Ford Explorer. In these instances, researchers determined what the vehicle was classified as in the majority of records, and all registrations with that make and model were adjusted to reflect the majority designation. In other words, if 51 percent of registrations involving a Ford Explorer were classified as 25, then all registrations for a Ford Explore were adjusted to class 25.

Assignment of Fuel Efficiency Ratings

Once the registrations were converted into a specific vehicle model, researchers assigned fuel efficiency ratings. Information related to the fuel efficiency of specific makes and models was obtained from the Environmental Protection Agency's (EPA) various fuel economy guides. Each year the EPA issues a new guide that covers all makes and models. Electronic files for each year for 1984 (the earliest year for which electronic files could be obtained) through 2010, the most recent issue. All of this information was input into a Microsoft Excel file that was used for fuel efficiency for assignment.

The fuel economy guide lists every make and model manufactured in that specific year along with the transmission type, engine size, cylinders, and fuel economy. Numerous estimated fuel efficiencies are provided for each make and model, but for this research the "combined efficiency rating" was used.

Often, there were several listings for the same model of car. These variations are due to differences in engine type, number of cylinders, etc. The converted registration information generally only distinguished between 4-wheel drive and 2-wheel drive models. Therefore, researchers took an average of the ratings for each model listed in the EPA guide.

For example, with a Ford Ranger, the 2010 guide lists six variations of this model—four of which are 2-wheel drive and two which are 4-wheel drive. The vehicle registration records obtained by researchers did not contain sufficient information that would allow for differentiation between 2- and 4-wheel drive. Therefore, researchers assigned all 2010 4-wheel drive Ford Rangers with a fuel economy of 16, an average of the 6 models provided on the EPA guide.

FINDINGS

Initial analysis of the data set revealed a wide variation in fuel efficiencies across the over 355,000 vehicle registration records collected in this study (Figure 4). The mean fuel efficiency for the entire data set was 20.52 mpg with a standard deviation of 5.03.

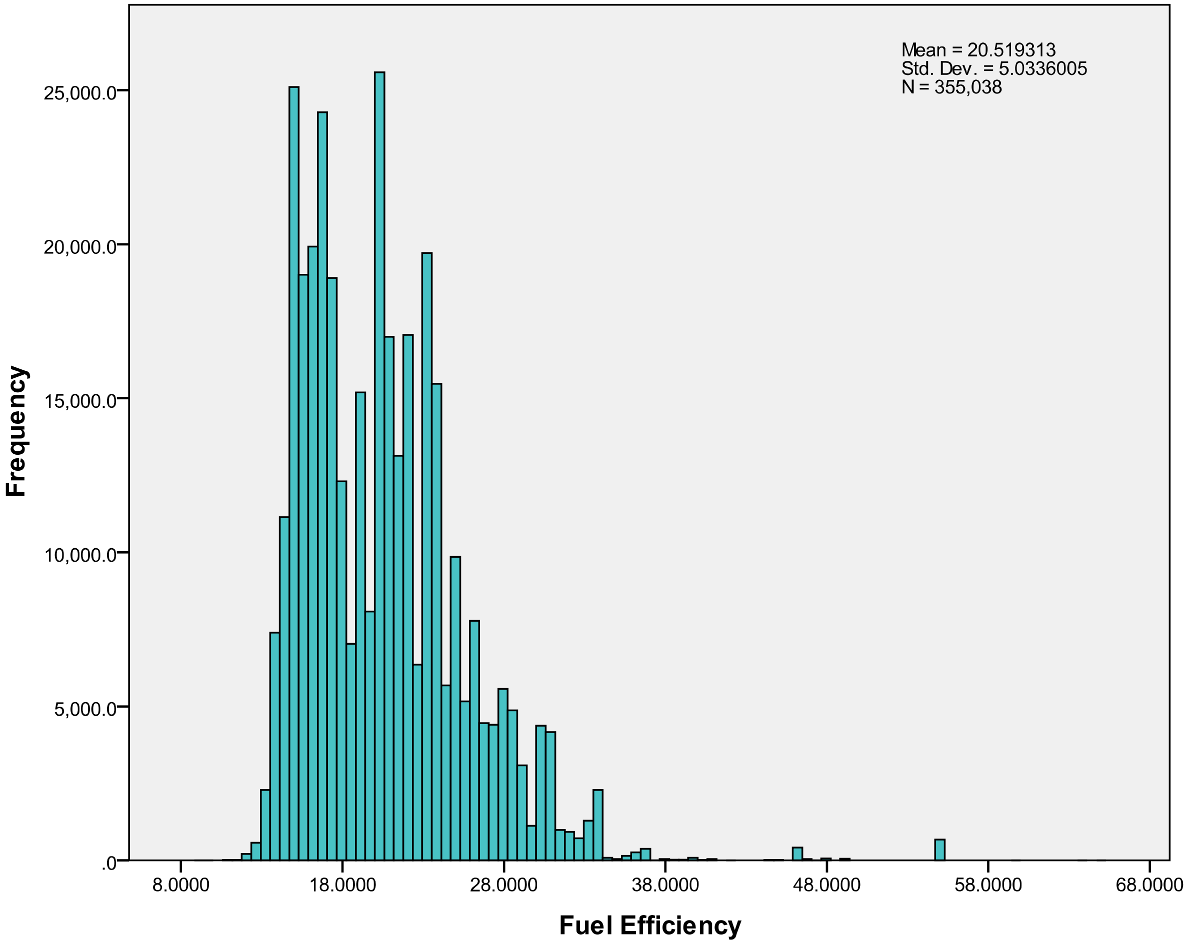


Figure 4: Histogram Plot of Fuel Efficiency (All Records)

An initial analysis of means of fuel efficiencies for the various zip codes (Figure 5) revealed that all were within one standard deviation of the main data set. The highest and lowest means were observed in zip codes with median household incomes of below $26,000. Median income for the state of Texas in the 2000 census was $39,927. However, these values occurred in zip codes with fewer records relative to others in the sample.

Zip Code	Median Household Income	Mean Fuel Efficiency	N	Std. Deviation
79901	$ 9,783	20.8024	4,791	4.9362
78401	$ 13,401	19.9289	1,969	4.7320
78205	$ 14,578	19.6298	1,257	5.1255
78705	$ 14,740	24.0353	4,626	6.1895
75210	$ 15,058	21.2799	2,933	4.5152
77003	$ 19,252	20.6161	5,142	5.0180
79101	$ 20,813	19.8635	1,947	4.4376
78520	$ 21,715	20.4948	31,678	4.6372
79842	$ 23,000	18.5786	507	5.2251
75702	$ 25,119	20.2749	16,187	4.4777
78361	$ 25,833	18.9684	3,174	4.1980
79701	$ 27,369	19.1338	18,631	4.5331
79072	$ 31,463	19.6679	16,462	4.4400
76230	$ 31,497	19.2396	7,782	4.5184
78526	$ 31,710	20.3752	16,538	4.6703
75654	$ 32,360	19.6737	7,071	4.6172
78606	$ 37,353	19.4988	4,206	5.0368
76208	$ 39,428	20.9055	11,359	5.0971
79109	$ 41,290	20.4472	31,920	4.7694
77006	$ 41,746	22.3836	12,632	5.8070
79908	$ 43,065	20.0749	771	4.8770
78621	$ 45,263	20.3643	14,337	5.0515
78209	$ 46,417	21.1945	33,258	5.3003
78410	$ 46,975	19.9007	15,813	4.7871
75707	$ 47,646	20.1524	9,894	4.8655
79707	$ 50,166	19.7381	21,208	4.7682
78154	$ 54,269	21.1299	22,660	5.1263
78703	$ 54,591	21.8161	13,078	6.0337
75201	$ 56,675	20.8361	6,419	5.0276
77005	$ 104,035	20.9910	16,788	5.4589

Figure 5: Mean Fuel Efficiency by Zip Code

The differences in means observed are statistically significant given the size of the samples involved. However, there is little observed consistency in terms of mean fuel efficiencies in various zip codes being above or below the total sample mean (Figure 6). The zip code with the highest average fuel efficiency (24.04) was 78705, corresponding to Central Austin, a zip code with a relatively low median income due possible to high university student population. The lowest average fuel efficiencies (18.58 and 18.97) were observed in Marathon and the Hebbronville, both of which are rural and have relatively low median incomes.

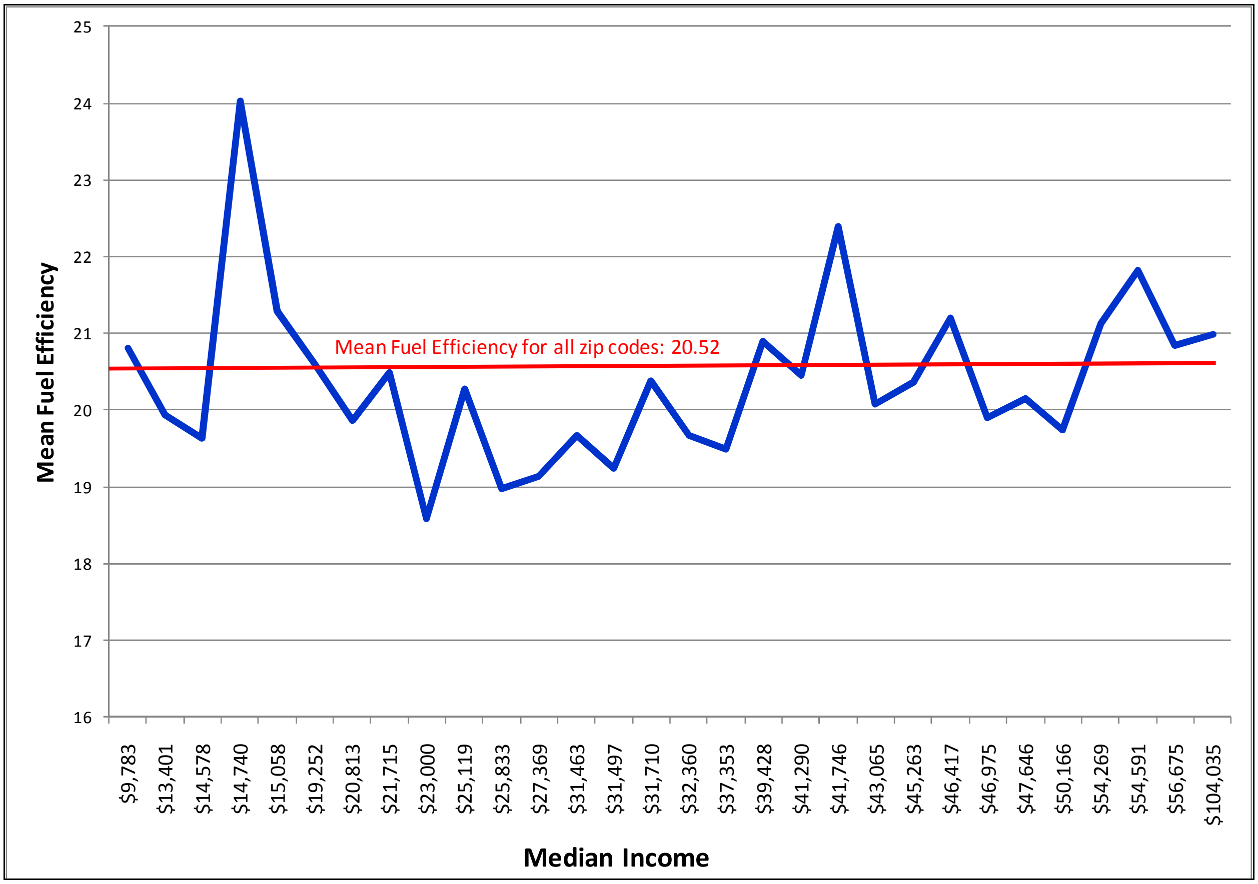


Figure 6: Mean Fuel Efficiency by Median Income of the Zip Code

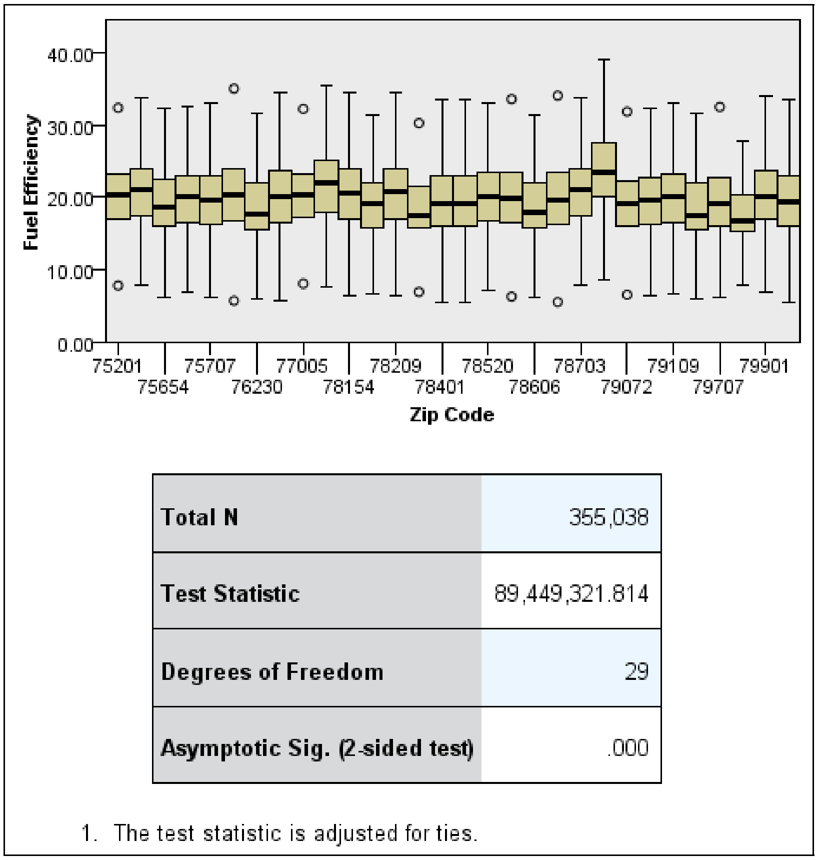
In order to determine if distribution of fuel efficiency for each zip code were statistically different from the larger sample of records, a Kruskal-Wallis analysis of variance test was run. This statistic is non-parametric (data need not have a normal distribution) and is used to compare three or more groups within a data sample. This test is also appropriate in that the sub samples that are being analyzed are not equal in size. The procedure for a Kruskal-Wallis test is as follows:

1. Data from each sub sample are arranged in ascending order.
2. A ranking is assigned to value in ascending order. Repeated values are assigned a ranking by averaging rank positions.
3. The ranks of the different sub samples are separated and summed in the form R_1, R_2, R_3, etc.
4. The Kruskal-Wallis test is performed by applying the following formula:

$$H = \frac{12}{N(N+1)} \left(\sum \frac{(T_g)^2}{n_g} \right) - 3(N-1)$$

Where: **H = Kruskal-Wallis Test**
N = total number of observations in all samples
T = Sum of all observations with rank *g*
n = Mean of all values within rank *g*

For this exercise, groups were classified by zip-code. SPSS statistical software was used to run the Kruskal-Wallis test, which revealed that the distributions of fuel efficiencies across all zip codes were not the same and that the difference between the means within each zip code was statistically significant.

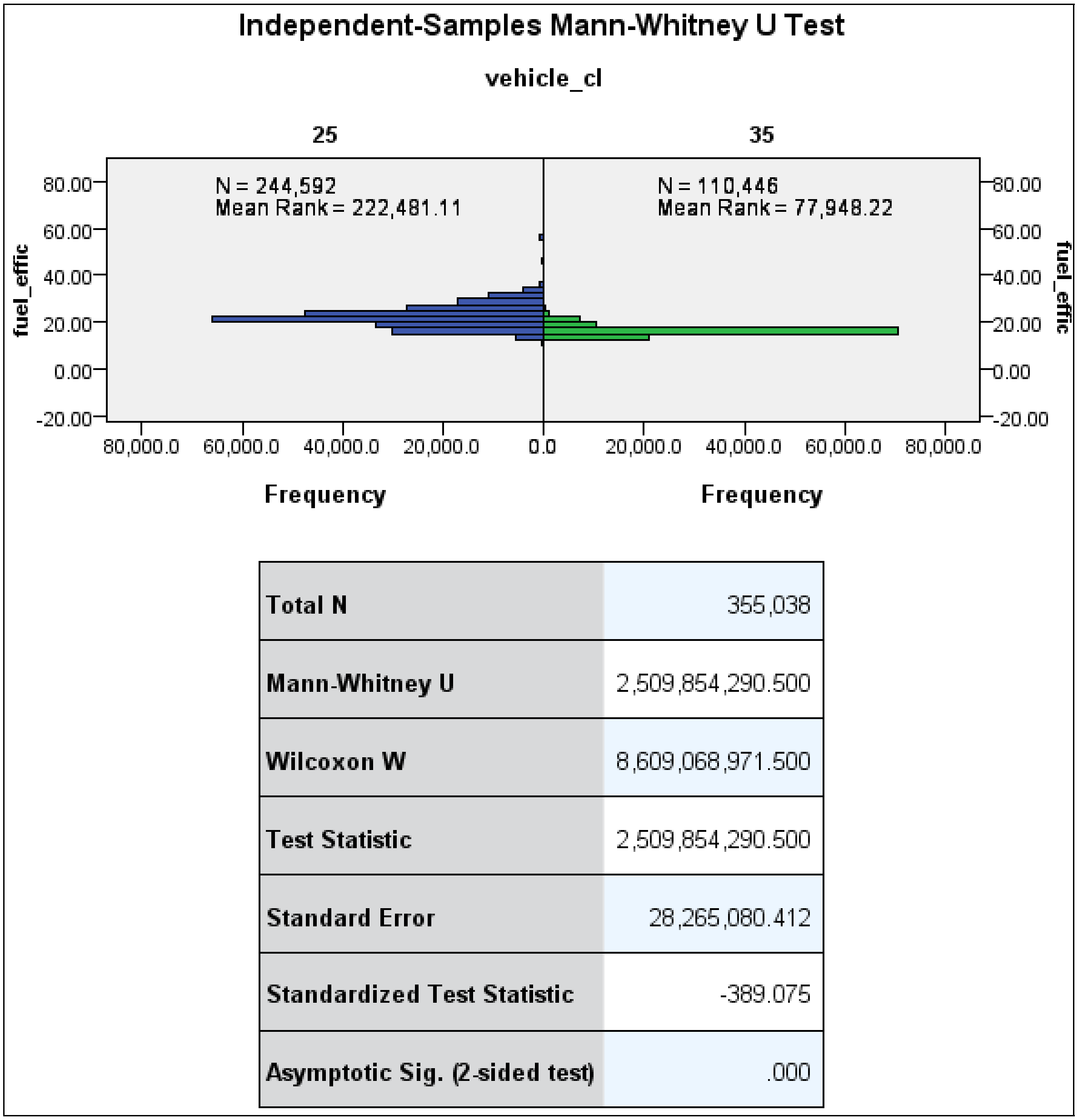


Total N	355,038
Test Statistic	89,449,321.814
Degrees of Freedom	29
Asymptotic Sig. (2-sided test)	.000

1. The test statistic is adjusted for ties.

Figure 7: Independent-Samples Kruskal-Wallis Test (Fuel Efficiency by Zip Code)

The analysis shows that there are differences in terms of the distribution of fuel efficiencies within the zip codes comprising the data set, but there is little else to indicate the nature of the relationship. Zip codes with a lower median income are not more likely to have lower average fuel efficiency, as might be expected. In order to further examine potential drivers behind the variability of fuel efficiency based on income and zip code, researchers conducted an analysis of average fuel efficiency based on vehicle class. It is possible that differences in the average fuel efficiency among class 25 and class 35 vehicles, and the distribution of these vehicles, might explain some of the variability observed in Figure 6. As can be seen in Figure 8, the difference in fuel efficiencies between class 25 (passenger vehicles) and class 35 (light duty trucks) was statistically significant.



Total N	355,038
Mann-Whitney U	2,509,854,290.500
Wilcoxon W	8,609,068,971.500
Test Statistic	2,509,854,290.500
Standard Error	28,265,080.412
Standardized Test Statistic	-389.075
Asymptotic Sig. (2-sided test)	.000

Figure 8: Analysis of Vehicle Class

The mean fuel efficiency for class 25 vehicles was 22.429, while the mean for class 35 vehicles was 16.290. Statistically, class 35 vehicles have lower fuel efficiency than class 25 vehicles. It is possible that zip codes with lower average fuel efficiency will have a higher distribution of class 25 vehicles.

Zip codes were next grouped by median income into “low,” “medium,” and “high.” This designation was based on 2000 census data related to household income (Figure 9). Designations were assigned such that 1/3 of the state population of households would fall within each category.

Household Income		Cumulative	Cumulative Percentage	
Less than $10,000	767,505	767,505	10%	Low
$10,000 to $14,999	491,154	1,258,659	17%	
$15,000 to $19,999	486,555	1,745,214	24%	
$20,000 to $24,999	517,568	2,262,782	31%	
$25,000 to $29,999	502,840	2,765,622	37%	Medium
$30,000 to $34,999	493,301	3,258,923	44%	
$35,000 to $39,999	445,431	3,704,354	50%	
$40,000 to $44,999	416,463	4,120,817	56%	
$45,000 to $49,999	357,464	4,478,281	61%	
$50,000 to $59,999	637,160	5,115,441	69%	
$60,000 to $74,999	722,277	5,837,718	79%	High
$75,000 to $99,999	705,684	6,543,402	88%	
$100,000 to $124,999	362,512	6,905,914	93%	
$125,000 to $149,999	173,506	7,079,420	96%	
$150,000 to $199,999	153,492	7,232,912	98%	
$200,000 or more	164,382	7,397,294	100%	

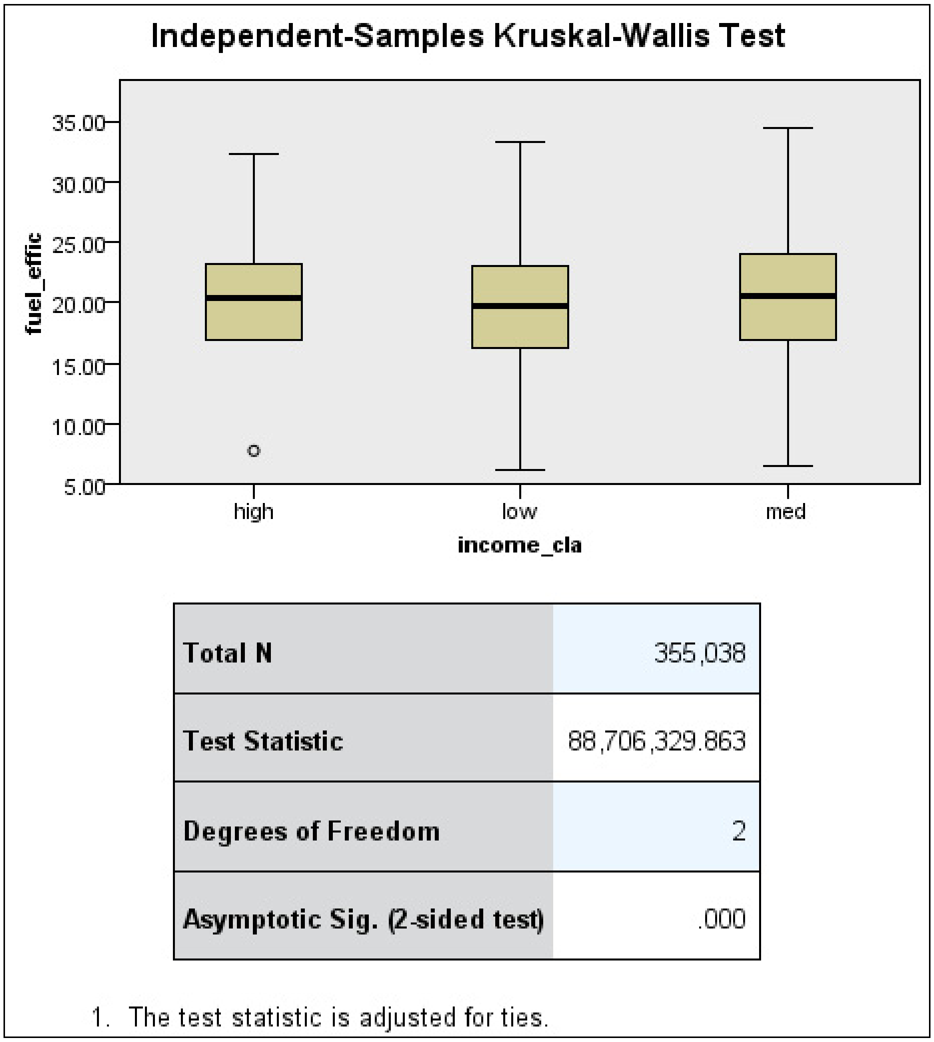
Figure 9: Median Household Income, Texas

Source: US Census Bureau

Zip codes with a median income of less than $25,000 were classified as low, those with a median income of between $25,000 and $60,000 were classified as medium, and those with a median income of over $60,000 were classified as high. The medium income group exhibited the highest average fuel efficiency with 21.098 miles per gallon, while the lowest average fuel efficiency was observed in the low income zip codes (Figure 10). A Kruskal-Wallis Test (Figure 11) reveals that the distributions in fuel efficiencies across the income classifications are indeed statistically significant.

Income Class	Mean Fuel Efficiency	Standard Deviation
Low	20.2954	4.8435
Medium	21.0980	5.4548
High	20.9481	5.3434
Total	20.5193	5.0336

Figure 10: Mean Fuel Efficiency by Income Class


Independent-Samples Kruskal-Wallis Test

Total N	355,038
Test Statistic	88,706,329.863
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.000

1. The test statistic is adjusted for ties.

Figure 11: Independent-Samples Kruskal-Wallis Test (Fuel Efficiency by Income Classification)

An analysis of vehicle classes illustrates why average vehicular fuel efficiency might be lower in low income zip codes (Figure 12). The low income zip codes had the highest percentage of class 35 vehicles at 35 percent. Class 35 vehicles decline as a percentage of the overall vehicle fleet for the other income zip codes, accounting for 23 percent for the medium zip codes and 16 percent for the high income zip codes.

	Vehicle Class		
Income Class	**25**	**35**	Total
Low	65%	35%	100%
Medium	77%	23%	100%
High	84%	16%	100%
Total	69%	31%	100%

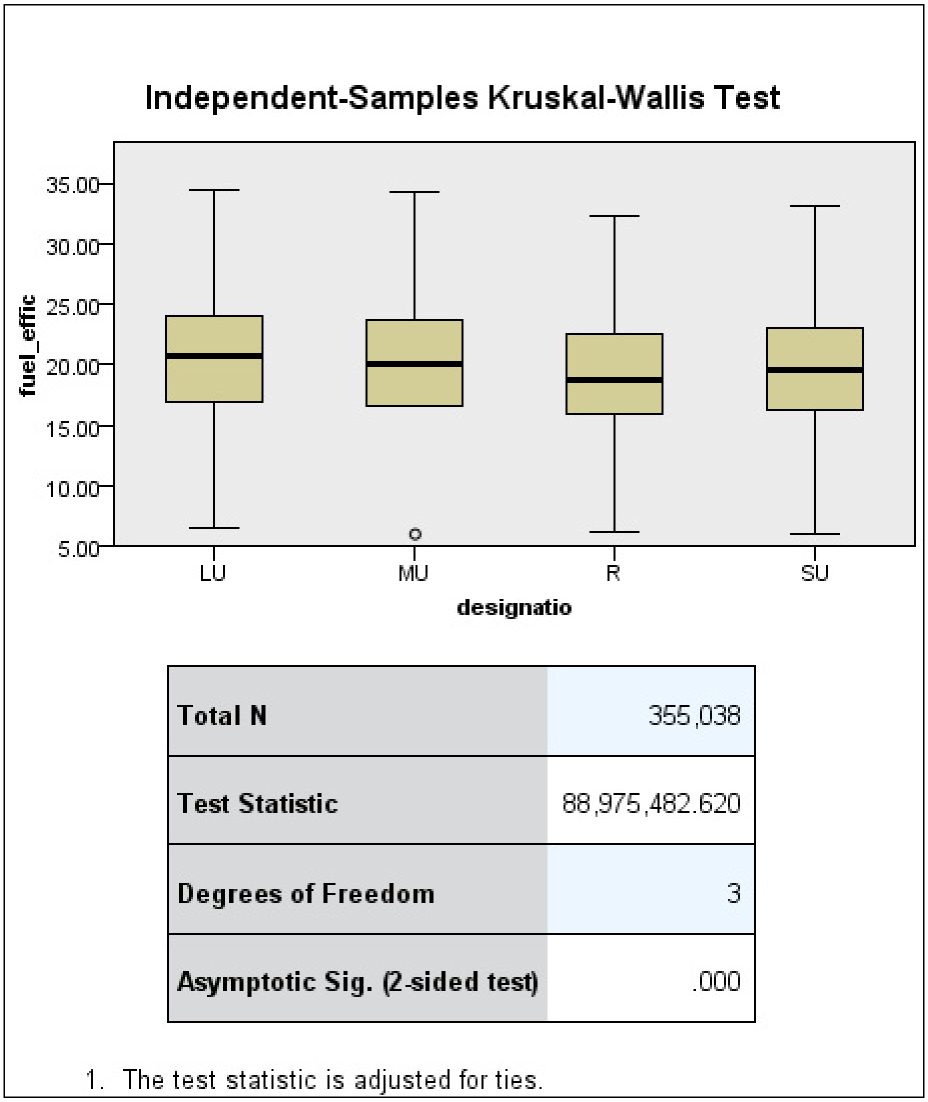
Figure 12: Vehicle Class by Income Class

For further analysis, zip codes were grouped by their classification in terms of urban versus rural. Zip codes within cities with a 2000 census population of 1 million or more (Dallas/Ft. Worth, Houston, and San Antonio) were classified as large urban (LU). Zip codes within cities with a population of less than 1 million but greater than 150,000 were classified as mid-sized urban (MU). Zip codes within cities with a population of less than 150,000 were classified as small urban (SU), and all other zip codes were classified as rural (R).

The lowest average fuel efficiency was observed in rural areas with 19.7278 miles per gallon (Figure 13). Large urban areas had the highest average fuel efficiency at 21.1933. Average fuel efficiency appears to decline with the size of the urban area. A Kruskal-Wallis test (Figure 14) reveals that the observed differences in distribution among the urban designations are statistically significant.

Designation	Mean Fuel Efficiency	Standard Deviation
Large Urban	21.1933	5.3018
Mid-Size Urban	20.7825	5.2201
Small Urban	20.0538	4.6729
Rural	19.7278	4.7082
Total	20.5193	5.0336

Figure 13: Mean Fuel Efficiency by Urban Designation



Total N	355,038
Test Statistic	88,975,482.620
Degrees of Freedom	3
Asymptotic Sig. (2-sided test)	.000

1. The test statistic is adjusted for ties.

Figure 14: Independent-Samples Kruskal-Wallis Test (Fuel Efficiency by Urban Designation)

As Figure 15 shows, the rural areas have a higher percentage of class 35 vehicles, and large urban areas have the largest percentage of class 25 vehicles. Class 35 vehicles account for 44 percent of vehicle registrations in rural areas, while they account for only 23 percent of registrations in large urban areas.

	Vehicle Class		
Designation	**25**	**35**	Total
Large Urban	77%	23%	100%
Mid-Size Urban	71%	29%	100%
Small Urban	65%	35%	100%
Rural	56%	44%	100%
Total	69%	31%	100%

Figure 15: Vehicle Classification by Urban Designation

CONCLUSIONS

The analyses performed showed that there were statistically significant differences in the distribution of fuel efficiencies across all zip codes, and that the median values for fuel efficiency were significantly different relative to the whole sample. Furthermore rural areas and lower income areas were shown to have lower average fuel efficiencies than urban and higher income areas. Much of this difference might be tied to the distribution of class 35 vehicles, which are comprised mostly of light duty pick-up trucks and SUVs. Class 35 vehicles make up a higher percentage of vehicle registrations in lower income and rural areas.

However, it is difficult to draw any additional conclusions from the data. One of the primary problems with the data analyzed was that income information could not be tied to each individual vehicle registration. Such data are simply not collected by registration entities. All registrations within a particular zip code were assumed to have the same income. Survey data could be utilized in order to more directly relate income to vehicle fuel efficiency, but this exercise was oriented toward utilizing existing data sets in order to determine any potential relationships.

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APPENDIX: ZIP CODE DATA

Zip Code	Area	Region	Designation	2000 Population (US Census)	Median Household Income (US Census)
75201	Dallas/Ft Worth	North Central	Large Urban	3,348	$ 56,675
75654	Henderson	East	Rural	11,706	$ 32,360
75702	Tyler	East	Small Urban	26,259	$ 25,119
75707	Tyler	East	Small Urban	10,956	$ 47,646
76208	Dallas/Ft Worth	North Central	Large Urban	10,929	$ 39,428
76230	Bowie	North Central	Rural	9,449	$ 31,497
77003	Houston	East	Large Urban	9,195	$ 19,252
77005	Houston	East	Large Urban	23,338	$ 104,035
77006	Houston	East	Large Urban	18,875	$ 41,746
78154	San Antonio	South	Large Urban	17,633	$ 54,269
78205	San Antonio	South	Large Urban	1,564	$ 14,578
78209	San Antonio	South	Large Urban	40,675	$ 46,417
78361	Hebbronville	South	Rural	5,274	$ 25,833
78401	Corpus Christi	South	Mid Urban	4,631	$ 13,401
78410	Corpus Christi	South	Mid Urban	22,633	$ 46,975
78520	Brownsville	South	Small Urban	48,601	$ 21,715
78526	Brownsville	South	Small Urban	26,395	$ 31,710
78606	Blanco	South Central	Rural	4,165	$ 37,353
78621	Elgin	South Central	Rural	16,299	$ 45,263
78703	Austin	South Central	Mid Urban	19,585	$ 54,591
78705	Austin	South Central	Mid Urban	26,825	$ 14,740
79072	Lubbock	North	Rural	28,684	$ 31,463
79101	Amarillo	North	Mid Urban	2,998	$ 20,813
79109	Amarillo	North	Mid Urban	46,005	$ 41,290
79701	Midland	West	Small Urban	24,981	$ 27,369
79707	Midland	West	Small Urban	26,304	$ 50,166
79842	Marathon	West	Rural	483	$ 23,000
79901	El Paso	West	Mid Urban	14,012	$ 9,783
79908	El Paso	West	Mid Urban	1,384	$ 43,065