The correlation of flammable liquid residential fires

with socioeconomic and climate factors

by

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ABSTRACT

Past research has revealed socioeconomic factors, such as income and education attainment, are correlated with safety, in general, and personal safety, specifically. Narrowing the focus of safety to fire, research has also revealed the incidence of residential fires is correlated with socioeconomic factors such as: family income, education attainment, and parental presence. Those fire studies involving more specific types of fires, such fires involving consumer products, household appliances, and other gas or electric products used in and around the home, have not studied the socioeconomic factors that might have been involved in those fires. Studies conducted in the past have revealed the quantity of these types of fires, but those studies did not attempt to determine if there were socioeconomic or climate factors involved in the fires. This research addressed this gap in the literature. This research concluded *education* had a significant inverse correlation with residential structure fires at the state level involving flammable liquids where the ignition source was a water heater. This research also concluded there was a significant correlation between *parental status* and residential structure fires involving flammable liquids. This research concluded *income* did not have a significant correlation with any of the fire variables using partial correlation. This study further concluded *climate* exhibited a significant inverse correlation with residential structure fires involving flammable liquids where the ignition source was a water heater or gas water heater. Prior research predicted climate (HDD) would have a significant correlation to the rate of fire incidents. This research concluded the climate exhibited an inverse correlation with some of the rates of fire incidents.

It is recommended that education and the inspection of flammable liquid fire hazards should be improved in the home in the states having a low HDD such as in the Southern United States. Those states with a low HDD exhibited a significant correlation between climate and the incidence of some types of fires. It is also recommended that fire prevention education be focused on single parent families. These recommendations are with the understanding that improved education and inspections may reduce the incidence of fires.

CHAPTER 1. INTRODUCTION

If one looks at safety as a general topic, safety has many subparts. Safety in general could be divided into categories such as: occupational safety, industrial safety, residential safety, vehicular safety, agricultural safety, maritime safety, fire safety, etc. Many other subcategories could be described as well. Generally, safety statistics are reported as safety factors, or personal injury statistics reporting the basic mechanics of how an injury may have occurred, or the quantity of a type (i.e., pedestrian, vehicular, power press, slip and fall) of event. These factors and reports do not typically describe the cause of injuries. In addition, the reasons behind the numbers and statistics in reports are seldom discussed. In general, socioeconomic variables are factors in personal injuries and safety (National Safe Kids, 2004). In 1999, there were 20,800,000 injuries in the United Sates. Of this total, 2,200,000 injuries involved automobiles, 3,800,000 involved work, and 6,900,000 occurred in the home (National Safety Council, 2000).

Problem of the Study

Narrowing the topic of safety statistics to fire statistics, fire statistics typically report basic mechanics of how or why fires start. Typical fire facts reported include: there were 1,755,000 fires in the United States in 1998 (U.S. Fire Administration, 2002), or residential fires account for 22% of all fires in the United States (U.S. Fire Administration, 2002). These facts inform researchers of important clues when analyzing fire incidents, but they do not offer other important information, such as: *Why are there more fire incidents in one geographical area than in another*, or *In what manner is human behavior involved in these incidences?*

The typical facts defining the mechanical causes of fires (i.e., number of fires in garages, number of fires caused by smoking materials, or number of fires caused by children playing with matches) do not explore the socioeconomic or environmental factors that may play a role in residential fires. Exploring the socioeconomic or environmental factors that may play a role in residential fires may lead to the development of better educational materials and methods to reduce the impact of these fires. The past studies involving socioeconomic factors involved in residential fires have not explored fires where flammable liquids or flammable liquids and appliances were involved.

Need for the Study

Research is needed to explore the correlation between the incidence of residential flammable-vapor fires and socioeconomic and climate factors as predictors of these fire incidents. Taylor (1987) examined the quantity of flammable liquid fires and ignition factors, as revealed in earlier National Fire Incident Reporting System (NFIRS) data sets. The examination revealed there were flammable liquid fires associated with typical household gas appliances which most people typically have in their homes. The Taylor study did not examine other factors, such as socioeconomic or climate factors, which may have some association to the cause of those flammable liquid appliance fires. Studying the socioeconomic and climate factors involved in residential fires where flammable liquids or flammable liquid and appliances were involved may lead to the development of better educational materials and methods to reduce the impact of these fires. The most important impact would be the reduction of deaths and injuries caused by these fires.

Research Questions

The following research questions guided the study:

1. To what extent is there a correlation between the incidence of residential structure fires with socioeconomic and climate factors?
2. To what extent is there a correlation between the incidence of residential structure flammable liquid fires with socioeconomic and climate factors?
3. To what extent is there a correlation between the incidence of residential structure flammable liquid fires involving water heaters with socioeconomic and climate factors?
4. To what extent is there a correlation between the incidence of residential structure flammable liquid fires involving gas-fired water heaters with socioeconomic and climate factors?

Previous research has not revealed studies examining correlations to specific types of structure fires, such as flammable liquid fires. More specifically, the current research examined residential structure fires involving flammable liquid fires and residential structure fires involving flammable liquid fires and water heaters to determine if there are comparable correlations with socioeconomic and climate factors between the current study and past studies for fire, in general.

CHAPTER 2. LITERATURE REVIEW

Socioeconomic Factors and Fires

Numerous socioeconomic factors are correlated to fires. TriData Corporation (1997) conducted a study entitled: *Socioeconomic Factors and the Incidence of Fire*, for the Federal Emergency Management Agency, United States Fire Administration, and National Fire Data Center. The study examined social factors related to the occurrence of fires. It reviewed fire incidence at the local level, to explore socioeconomic factors that relate to fire incidents. The TriData study revealed that socioeconomic indicators, such as parental presence, poverty, and under-education of persons over the age of 25, accounted for over 39% of the variation in fire rates in their geographic research area (TriData Corporation, 1997, p. 3). TriData also found that "parental presence, good education, adequate income, and home ownership were negatively correlated with fire rates" (TriData Corporation, 1997, p. 4).

Gunther (1981) examined various causes of fires in the inner city and found a correlation between income, race, education, and single parent homes. Seven factors of fire cause were examined: incendiary/suspicious, smoking, cooking, children playing, heating, electrical distribution, and appliances. Gunther noted these factors were generally tied directly to human actions, rather than being caused by mechanical malfunction. The findings also revealed geographic areas with lower median incomes had higher fire rates. A recommendation was made that public education programs regarding fire safety aimed at low-income neighborhoods would reduce the number of fires in those areas (Gunther, 1981).

Jennings (1996) opined that socioeconomic and environmental factors outweigh fire suppression factors. Jennings determined that fire risks have not declined at the same rate for all groups of people and, therefore, socioeconomic factors are likely more important for explaining the relative risk of residential fires. Jennings also revealed the cause of many fires was carelessness on the part of the occupants. Furthermore, "recent studies indicate that intervening in this pattern of behavior can be effective in reducing fire incidence without major investment in equipment or the passage and enforcement of retrospective building code changes" (Jennings, 1996, p. 10). Bugbee (1978), named the three principal causes of fire: men, women, and children. He stated: "far too few people are aware of fire prevention and fire safety" (p. 125).

A recent study conducted in New Zealand (Duncanson, Woodeard, & Reid, 2002) examined fatal unintentional domestic fire incidents in that country and compared them to census information including income. The researchers found the incidence of fatal unintentional domestic fires occurred "disproportionately" in homes in the most socioeconomically deprived areas. The New Zealand study indicated those in the lowest income areas had significantly higher rates of fatal fires.

Duncanson et al. (2002) used a socioeconomic index which included nine variables, eight of which were obtained from the 1996 census information. The nine variables used were:

> 1. communication (people with no access to a telephone, 2. income (people aged 18-59 years receiving a means-tested benefit), 3. income (people living in households with equivalised income below an income threshold), 4. employment (people aged 18-59 years not employed), 5. transport (people with no access to a car), 6. support (people aged less than 60 year living in a single parent family), 7. qualifications (people aged 18-59 years without any qualifications), 8. owned home (people not living in own home), 9. living space (people living in households below equivalizes bedroom occupancy threshold). (p. 167)
> [Note, Equivalisation refers to methods used to control for household composition.]

"Meshblock" (geographic census tract) geographic information was used to define the areas of study to combine the census information and fire information for those areas. The use of census information at the geographic census tract level has been made by other researchers such as Jennings (1996), and Karter and Donner (1978).

Duncanson, Woodward, and Reid (2002) divided the socioeconomic index into 10 levels, with the 10^{th} being the lowest, or most deprived level. Twenty percent of all the fatal fires in the New Zealand study involved the 10^{th} level of the index, whereas only 4% of the fatal fires were in level 1. Forty-nine percent of all the fatal unintentional domestic fire incidents involved the lowest (most deprived) three levels, 8, 9, and 10, clearly indicating the more deprived an area, the higher the rate of fatal fires. Duncanson et al. (2002) noted that these findings were "consistent with international observations of the increased fire rates in socioeconomically deprived population groups" (Duncanson et al., 2002, p. 170). In addition, they found a positive correlation with the following factors: under-education, housing over-crowdedness, and poverty.

Duncanson et al. (2002) also examined how sole parenthood impacts the fatal unintentional domestic fire incidents. The researchers found that children of a lone parent have especially high death rates in New Zealand, which they associated with poverty, poor housing, and increased smoking rates. One factor Duncanson et al. (2002) found to "significantly" impede the compliance of safety messages was low education level. Jennings (1996) also concluded that low education level was correlated to increased fire rates.

In conclusion, Duncanson et al. (2002) found that an increased rate of unintentional domestic fatal fires occurs with increased socioeconomic deprivation at the mesh block level.

They recommended that there is a need to address "barriers" (low education, lone-parent households, low income) to improve household safety in deprived areas.

Chandler, Chapman, and Hollington (1984) examined 15 housing and socioeconomic parameters for three cities in England. The 15 housing and socioeconomic parameters (proportions) examined were: (1) owner occupation; (2) private rented housing; (3) population density/hectare; (4) housing lacking at least one of three basic amenities; (5) overcrowding in houses (more than 1.5 persons per room); (6) shared households; (7) dissatisfied with housing; (8) people in socioeconomic groups IV and V; (9) people unemployed; (10) people under age 15 years old; (11) people aged 65 and over; (12) children in care; (13) illegitimate births; (14) people of African or Caribbean origin; and (15) people of Indian sub-continent origin. The researchers found there was a significant correlation with three social parameters—proportion of owner occupation, social economic group, and unemployment in the three cities. This study examined census data of the Birmingham, Newcastle-Upton-Tyne areas, and London communities in the U.K. It was determined that the owner-occupied home factor had an inverse correlation with the fire rate in all three communities. Population density was a significant factor in London, but did not correlate with findings in Birmingham and Newcastle.

Ignition sources were also studied by Chandler et al. (1984), specifically those that were thought to reflect carelessness, lack of supervision, or vigilance. The sources included: children with fire, smoker's materials, malicious or doubtful ignition, and unknown. Findings from London and Birmingham indicated that owner-occupied, population density, and socioeconomic groups were significantly correlated to careless ignition of fires.

According to the results of the study (Chandler et al., 1984), all three communities had fire incident rates that correlated directly with socioeconomic groups and unemployment, and negatively correlated with owner occupation. In London there was a correlation of fire incidence with family instability, where family instability was defined as children in care of the family was used as the measure of a socioeconomic parameter. Furthermore, it was noted that the "problem" areas (areas where there were more fires) were very localized and smaller than originally perceived. The researchers recommended the need to identify high risk areas and investigate the effectiveness of public fire safety education programs on television or house-to-house communication.

Karter and Donner (1978) conducted a study entitled: The effect of demographics on fire rates. This study was sponsored by the National Fire Protection Association (NFPA) research division to analyze the census information and fire data at the census tract level. The researchers looked at five cities: Kansas City, MO, Syracuse, NY, Newark, NJ, Phoenix, AZ, and Toledo, OH. The average census tract size was about 4,000 residents. Factors examined were: race, poverty, affluence, unemployment, under-education, family stability and age. House characteristics, such as owner occupancy, crowdedness, vacancy and structure size, were also considered. The purpose of the study was to improve fire prevention work through inspections, education, and enforcement in areas with a higher risk.

The Syracuse information revealed an increase in fire rates for those families that had a lower percentage of children under the age of 18 living with both parents in the home. An explanation for these results was not offered. Over-crowdedness was related to an increase in fires rates. The map showing the census tracts in Syracuse where lower family stability and the map showing over crowdedness were the geographic areas with higher fire rates and these census tracts appeared to be nearly the same tracts. In Newark, poverty was related to an increase in fire incidence, and ownership was inversely related to the fire rate. In Phoenix, poverty and crowdedness were determined to be related to the increase in the incidence of fire. The map showing the census tracts in Phoenix where poverty was located and the map showing over-crowdedness were geographic areas with higher fire rates. In addition, these census tracts appeared to be nearly the same tracts. The same was true for the census tracts in Newark regarding poverty and ownership in high-risk areas.

The areas where the study indicated high risk factors being nearly the same led the current researcher to the conclusion that there is an interrelationship among these variables. The research in Toledo regarding poverty and ownership followed the same patterns seen in the previous cities, that is, there is a relationship between poverty and increased fire rate, and an inverse relationship between ownership and fire rates. Again, the census tracts maps were nearly identical.

Gilliam (1985) examined fire patterns in Highland Park, Michigan, using census block and tracts. The fire study examined arson, cooking, smoking, electrical, miscellaneous, and unknown fire patterns from fire reports for the years 1970 and 1977. Gilliam opined prior prevention approaches focused on the physical problems but not the social structure. The turning point of this assumption was based on a fire report entitled: *America Burning* (U.S. Fire Administration, 1973). Gilliam concluded from this report there were many problems with training, equipment, combustion research, and prevention. According to Gilliam, due to the *America Burning* report, research began in earnest focusing on the physical causes of fires; however, it failed to look in detail at the social factors that were involved.

Fahy and Norton (1989) examined the socioeconomic factor, poverty and fire risk by assessing poverty and fire incidents in urban and rural areas. Their research revealed that past studies had linked poverty and high fire rates in both areas, however, fire safety programs, public education efforts, codes, and standards, product design, and auto detection had not produced the intended impact on the part of society that is most at risk—the poor. "The fire community must understand how being poor adds to fire risks and hinders efforts to reduce those risks" (Fahy & Norton, 1989, p. 30).

The overall factors strongly related to fires were: poverty, under-education, and parental presence (Fahy & Norton, 1989). Overall, cities with higher levels of poverty showed higher levels of fire rates. When examining rural fire and poverty relationships, Fahy and Norton (1989) found that, at the state level, southern states had more poverty than northern states. The southern states were: Alabama, Arizona, Arkansas, Florida, Georgia, Louisiana, Mississippi, New Mexico, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and three high poverty border states: Kentucky, West Virginia, and Virginia. States with high poverty rates had a strong correlation between rural poverty level and rural fire rates.

Fahy and Norton (1989) noted the National Bureau of Standards' Center for Fire Research conducted a similar study (Gomberg & Clark, 1982) regarding seven southern states which indicated the most common causes of fatal rural residential fires were: heating, smoking, cooking, and electrical distribution. The major factor in the difference between rural and urban fires was heating. There were less heating fires in urban areas than in rural areas. Fahy and Norton concluded:

> "Heads of poor households are less likely to have high-school educations, so they may not grasp the full import of public fire safety education messages. If they do grasp the messages, they are more likely to lack the discretionary income to obtain smoke detectors, or safe heating systems, or code complaint electrical service, or fire safe security measures, or anything else that involves buying a larger measure of fire safety." (p. 36)

Spending extra time and resources to design and implement fire safety strategies that make sense for the poor will reduce the risk of fire to this population (Fahy & Norton, 1989).

Fahy (1993) examined fires related to unsupervised children and noted there is a statistical pattern indicating unattended or unsupervised children are a significant problem. Factors include: children who get up before their parents, parents or care givers who are napping, and parents and care givers who are in another part of the house and are not watching the children. According to Fahy, the major cause of home fires killing preschool age children between 1985 and 1989 was children playing (34%). Fahy concluded that reducing the number of deaths by fire of unattended and unsupervised children would involve better education of the parents and children to the dangers of fire. Fahy indicated many people do not understand how short a time it takes for a fire to grow and become out of control. In addition, people underestimate how easy it is for children to start fires. A point Fahy (1993) made was that lighters must be kept out of the reach of children.

TriData Corporation (1998) concluded a colder climate was a factor in predicting higher fire incidence in cities. This is because flame-fired home heating appliances are in greater use during colder months. TriData Corporation (1998) also determined that cooking fires and socioeconomic factors were not a strong predictor of appliance fires (pp. 19-20).

For decades, the National Fire Protection Association (NFPA) has been funding, researching, producing, and providing educational programs geared to educating the public about fire safety. Several of their campaigns are focused on young children and their families. The campaigns targeting young children focus on fire prevention, and typically use Sparky, the dog, to teach fire safety. Stop, Drop, and Roll is a safety campaign for children facilitated by local fire departments.

Schaenman et al. (1990) studied the problem of public fire education in the United States. They examined several public fire prevention education programs around the country to determine if they were successful. They found many of the programs were successful by examining the fire rates in communities where there were fire education programs in place and communities where there were no fire education programs in place. Public support and funding were the major barriers for having the programs work. In those parts of the country where the programs had been given adequate funding and support, fire incidents declined. In another study, Schaenman et al. (1987) examined public fire education programs and concluded they were under funded and feared education would not help reduce fires. A secondary outcome of the current research might be to support the establishment of a specific fire safety educational program or more fire safety education in specific geographic areas, based on local climate or socioeconomic factors.

Table 1.1 provides a summary of the resources identifying socioeconomic factors examined in the current study. Income was the only socioeconomic factor examined in all of the studies. Two factors, education and parental status, were examined in all but one study.

Table 1.1. Resources which examined socioeconomic factors

Socioeconomic factors	TriData 1997	Gunther 1981	Duncanson et al. 2002	Chandler 1984	Karter & Donner 1978	Fahy & Norton 1989	Fahy 1993
Income	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Education	Yes	Yes	Yes		Yes	Yes	
Parental status	Yes	Yes	Yes		Yes	Yes	
Crowdedness			Yes	Yes	Yes		
Smoking materials			Yes	Yes	Yes		
Children w/ fire				Yes			Yes
Malicious fire				Yes			
Family stability				Yes	Yes		Yes
Home ownership	Yes		Yes	Yes	Yes		
Telephone			Yes				
Employment			Yes	Yes			
Child supervision				Yes			Yes
Race		Yes					

Home Appliance Fires

Ray, Anderson, Padmanaban, and McCarthy (1991) studied the risk analysis of home appliances by examining fire incidents provided by the National Fire Incident Reporting System (NFIRS) from 1979 through 1988, and the Consumer Product Safety Commission's (CPSC) National Electronic Injury Surveillance System (NEISS) information. Information regarding the number of homes and appliances was acquired from the Energy Information Administration's Residential Energy Consumption Survey. The study examined: appliance malfunction, material first ignited, room of fire origin, equipment involved in ignition, and form of heat of ignition, and compared those factors to injuries involving home appliances. Ray et al. (1991) found that more than 65% of home fires were unrelated to appliances and were attributed to ignition sources like smoking materials, electrical shorts, and children playing. The residential fires that were involved with home appliances, ovens, and ranges accounted for 15% of all residential fires and approximately 50% of the appliance fires in the study. Ray et al. (1991) concluded that no clear trend to fires was found between correctly operating appliances and malfunctioning appliances.

Home appliances were also selected and compared with the corresponding estimated annual injury risk in 1984 (Ray et al, 1991). They found that the risk of fire injury per million households was of 19.3 for ranges and ovens, 6.9 for water heaters, 50.1 for grills, and 3.6 for dryers. Clearly, ranges and ovens were related to a higher risk of fire injury with those appliances used in the home (excluding grills). The researchers concluded programs for the prevention of fire and burn injuries from home appliances should focus on home appliances, such as ranges and ovens that are most associated with fires and injuries.

Taylor (1987) and Harwood (1982) conducted studies involving flammable vapor water heater fires but did not examine socioeconomic factors that may have been involved in the fires. Taylor conducted an empirical study of residential structure fires that involved flammable liquids by examining fire incident information acquired through the National Incident Reporting System (NFIRS). Taylor (1987) determined that an average of 13,560 structural fires involved flammable or combustible liquids annually between 1980 and 1984. Two-fifths (40.4%) of the reported incidents involved incendiary or suspicious fires, or fires that were set or appeared to have been set, but had nothing to do with a mechanical failure. Taylor also noted that 41.5% of the flammable liquid incidents and 76.0% of the injuries from these incidents involved the misuse of the material ignited. Approximately 40% of the fires were suspicious, and that a similar percentage involved the improper handling of a flammable or combustible liquid which, together, account for over 80% of all fire incidents involving flammable and combustible liquids. The remaining 20% of the incidents involved: misuse of the heat of ignition; mechanical failure/malfunction; design, construction, installation deficiency, or operating deficiency; natural condition; operating deficiency; and other ignition factors. In addition, Taylor (1987) also determined that 15.4% of the incidents involved water heaters.

Harwood (1982) researched fire hazards associated with gas water heaters by examining 139 in-depth investigations from the Consumer Product Safety Commission's epidemiological data from 1980 to 1982. After finding only seven flammable liquid injuries involving water heaters, Harwood concluded the ignition of gasoline or other flammable vapors was a smaller hazard than expected, but advised that a larger warning was required on the appliance.

Table 1.2 provides a summary of the findings of the resources examined in this study associated with home appliance fires. Ray (1991) offered an injury rate for the ignition factor listed here. The ignition factors listed are only those of interest in the current study, specifically gas appliances. Taylor (1987) offered a percentage of the residential structure fires that involved these ignition factors. Harwood (1982) provided the number of fires involving that particular ignition factor.

Resources Searched

The following general library catalogs, search engines, organizational data bases, and journals were searched for literature pertaining to residential fire incidents and socioeconomic factors:

1. The Iowa State University Library,
   a. general catalog
   b. dissertations and thesis at Iowa State University

Table 1.2. Home appliance fire resources

	Resources examining home appliance fires		
Ignition factors	Ray 1991	Taylor 1987	Harwood 1982
Ovens and ranges	19.3 injuries/mil (15% of fires)		
Water heaters	6.9 injuries/mil	15.40% (of flammable liquid fires)	139 fire
Dryers	3.6 injuries/mil		
Flammable liquids		41.50% (of residential structure fires)	7 fires
Malicious fires		40.40% (of residential structure fires)	
Misuse of material		40% (of residential structure fires)	
Misuse of heat of ignition		20% (of residential structure fires)	
Grills	50.1 injuries/mil		

   c. dissertations and thesis nationally using ProQwest at Iowa State University Library
   d. journal index at Iowa State University
2. World wide web using,
   a. Google
   b. Metacrawler
   c. Webcrawler
   d. ProQwest
   e. Ask Jeeves
   f. Eric
   g. Northern Light
   h. Alta Vista
3. National Fire Protection Association,
   a. NFPA library
   b. NFPA Fire Journal
   c. NFPA data base
4. Federal Emergancy Management Agency,
   a. FEMA library
   b. FEMA data base
5. Consumer Product Safety Commission,
   a. CPSC publications
   b. CPSC data base
   c. CPSC library
   d. CPSC recall
6. National Fire Incident Reporting System,

a. NFIRS library
b. interview analysis
7. National Technical Information Service,
a. NTIS library
b. interview analysts
8. National Fire Date Center,
a. NFDC library
b. interview analysts
9. National Fire Administration,
a. NFA library
b. interview analysts
10. The previous sources were searched using the following keywords:
a. fire
b. Demographic and fire
c. Demographic and fire and research
d. Demographic and fire and study
e. Fire and study
f. residential fire
g. fire research
f. urban fire
h. fire and socioeconomic
i. flammable vapors
j. gasoline fire
k. gasoline fire injury
l. gasoline injury
m. flammable vapor fire
n. water heater
o. water heater fire
p. gas water heater fire
q. gasoline water heater fire

CHAPTER 3. METHODOLOGY

Selection of a Method to Examine the Data

The current research explored socioeconomic variables: education, income, parental status, and climate to determine if these variables correlate with the overall incidence of residential structure fires, residential structure/flammable liquids fires, residential structure/flammable liquids fires /water heater fires and residential structure/flammable liquids fires/gas water heater fires. These variables were used to determine if there is a correlation to flammable liquid fire incidence. It was expected that climate and the socioeconomic variables would have a statistically significant correlation to fire incidents. Specifically, it was hypothesized that the socioeconomic variables of a state's median household income and the state's percentage of the population with a high school education and the state's average climate (heating-degree-day value) would be correlated to the number of flammable liquid fires. It was also perceived that the state's percentage of single-parent, female head-of-households would be positively correlated to the number of incidents involving the selected fire types in a given state.

To be able to the answer the four research questions an analytical method was needed to provide information about the statistical correlations or associations between the numbers of fires in a state and socioeconomic and climate variables. Past studies have utilized a variety of analytical methods to come to their conclusions. The analysis method of past researchers was examined to determine which method might best be used to analyze the data to answer the research questions:

1. To what extent is there a correlation between the incidence of residential structure fires with socioeconomic and climate factors?
2. To what extent is there a correlation between the incidence of residential structure flammable liquid fires with socioeconomic and climate factors?
3. To what extent is there a correlation between the incidence of residential structure flammable liquid fires involving water heaters with socioeconomic and climate factors?
4. To what extent is there a correlation between the incidence of residential structure flammable liquid fires involving gas-fired water heaters with socioeconomic and climate factors?

Methodologies Applied in Previous Investigation

The previous studies examined in this research used several different methods of analysis. Chandler (1984) and Duncanson (2002) utilized correlations to analyze their data. Neither researcher reported any issues regarding the use of an analysis method. Taylor (1987), Karter and Donner (1978), Fahy et al. (1989), Ray (1991), and Fahy (1993) utilized empirical analyses in their studies. Gilliam (1985) used Chi-square whereas Gunther (1981), Jennings (1996), and TriData Corporation (1998) used regression to analyze their data.

Jennings (1996) faced several issues when applying regression statistics. His statistical model included variables which caused collinearity issues. Jenning's model revealed there was an interrelationship between some of his variables which caused difficulties when interpreting the results. Collinearity is a problem that arises when there is a moderate to high intercorrelation among the predictor variables used in regression analysis.

This is caused by two or more of the independent variables being highly correlated to each other, that is they are measuring the same entity.

To avoid similar issues faced by Jenning (1996), the current study used partial correlation to reduce potential collinearity problems. Furthermore, the sample size available for analysis in the current study was small, less than 40 values. The small sample size, which can reduce the validity of a regression model, discouraged the utilization of a regression analysis in this study. However, regression analysis was used to confirm the correlation results, with appropriate checks for validity of assumptions, (specifically normality) underlying the regression results.

Methodology Used in the Current Study

This research used the first-order correlations to relate specific socioeconomic and climate information to state fire data. Partial correlation was selected because it seeks to determine if there is a significant linear correlation between the number of fires in a state and the socioeconomic and climate variables. Furthermore, partial correlation was selected to determine what effect the socioeconomic and climate variables have on correlation to the numbers of fires in a state individually or in combination. This analysis tool enables the control of one or more of the independent variables (i.e., the socioeconomic and climate variables) to determine their effect in the correlation (George & Mallery, 2001). This analysis used two-tailed tests in all of the correlation tests. The variable correlation directions of the partial correlation tests involved in this study were uncertain to match the correlation directions of the variables as predicted in the literature review. Therefore a two tailed partial correlation test was used throughout this analysis.

According to Abrami, Cholmsky, & Gordon (2001) the model for Pearson's product moment correlations was used to determine the first-correlations, and then the results are applied in a partial correlation model.

According to Pearson's product moment correlation:

$$r = \frac{\sum (A_i - \bar{A})(Y_i - \bar{Y})}{\sqrt{\sum (A_i - \bar{A})^2}\sqrt{\sum (Y_i - \bar{Y})^2}} \tag{1}$$

where:
r = Pearson's product moment correlation ($-1<r<+1$)
A_i = variable 1, predictor variable (Fires per 100 thousand people, Flammable vapor fires per 100 thousand people, Flammable vapor water heater fires per 100 thousand people, Flammable vapor gas water heater fires per 100 thousand people)
$\bar{A}$ = variable mean (Fires per 100 thousand people, Flammable vapor fires per 100 thousand people, Flammable vapor water heater fires per 100 thousand people, Flammable vapor gas water heater fires per 100 thousand people)
Y_i = variable 2 (education, income, parental status, and heating degree day)
$\bar{Y}$ = variable mean (average education, income, parental status, and heating degree day)

The sample partial correlation is calculation as:

$$r_{YX.WO} = \frac{r_{XY.O} - r_{XW.o}r_{YW.o}}{\sqrt{(1-r^2{}_{XW.O})(1-r^2{}_{YW.o})}} \tag{2}$$

where:
r = ($-1< r_{YX.WO} <+1$)
X = variable one, predictor variable (Fires per 100 thousand people, Flammable vapor fires per 100 thousand people, Flammable vapor water heater fires per 100 thousand people, Flammable vapor gas water heater fires per 100 thousand people)
Y = variable two (education, or income, or parental status, or heating degree day)
W and O = variables that are being controlled for in the model, (education, or income, or parental status, or heating degree day).

The partial correlation will provide correlation coefficients for each of the variables that are used in the calculation. Those variables that are used as control variables are also used in the calculations, however their effect on the correlation coefficients of the other variables is subtracted out and therefore the resulting correlation coefficients exhibit their effect only and not that of the controlling variable(s). This is not the same as excluding that variable in the correlation calculation. The absence of that variable(s) from the calculation would not have allowed the included variables to be effected by its (their) presence and therefore no information about the effect would be known.

The four fire variables were examined using their respective residual plots. Those values which depicted non-normality were considered outliers and excluded.

The social and economic variables examined were selected based on the past research by Karter and Donner (1978), Gunther (1981), Tri Data (1997) and Duncanson et al. (2002). The variables selected were found to be correlated to general fires in these previous studies. The same socioeconomic variables were used in the current research to enable direct comparison of the results with previous studies. The variables selected were: a state's average education attainment for persons over 24 years of age, a state's median household income, and the percentage of a state's households that consists of single-parent household with a female head of household. The climate factor examined was a state's heating degree day value, (HDD) number. Each of these variables was compared to four state residential structure fire statistics measures:

1. Number of residential structure fires in a state, here after called *residential structure fires*;
2. Number of residential structure fires in a state involving flammable liquids, here after called *flammable liquid fires*;

3. Number of residential structure fires in a state involving flammable liquids and all types of residential water heaters, here after called *water heater fires*; and
4. Number of residential structure fires in a state involving flammable liquids and gas residential water heaters, here after called *gas water heater fires*.

Selection of Data Sets

The fire data in the current study were selected based on research by Taylor (1987), who used selected NFIRS coding to select the specific fire statistics. The current study used similar coding to Taylor (1987) to ensure this study would be similar to the previous study. The variable, state's average education attainment for persons over 24, here after referred to as *education*, was taken from the National Center for Education Statistics (*Digest of Education Statistics*, 2001). Income represented a state's median household income, obtained from the United States 2000 Census (2000b), here after called *income*. Parental status represented the percentage of a state's households that consists of single-parent families with a female head of household with children in the home, also obtained from the United States 2000 Census (2000a), here after referred to as *parent status*. The climate variable examined represented a state's heating degree day (HDD) number (National Climate Data Center, 2002), here after referred to as *climate*. This climate information was obtained from the National Climatic Center (2002). The National Climate Data Center could provide only HDD values for the 48 contiguous states, it excluded Alaska and Hawaii. The National Climate data also did not include a separate HDD value for the District of Columbia, because that value was included in the Maryland HDD value. This study used the Maryland heating-degree-day value for both Maryland and the District of Columbia. The state of Alaska HDD value was calculated from climate data provided by the Alaska Climate Research Center

(Alaska Climate Research Center, 2004). That data included 120 weather reporting stations, many in urban areas, which were averaged and used as the climate variable value in this study. The state of Hawaii HDD value was calculated from climate data provided by the Hawaii State Climate Office (Hawaii State Climate Office, 2004). That data included 118 weather reporting stations, many in urban areas, which were averaged and used as the climate variable value in this study.

The National Fire Protection Association (NFPA) develops and revises a series of codes that define and establish fire safety requirements. One such code is entitled: *Standard Classifications for Incident Reporting and Fire Protection Data NFPA 901* (National Fire Protection Association, NFPA No. 901, 1995b). It was prepared by the Technical Committee on Fire Reporting and adopted by the NFPA. This code defines how the participating fire departments nationwide report their individual fire incidents to the National Fire Incident Reporting System (NFIRS). The NFPA 901 code allows all the departments to report their incidents the same way, allowing the data to be organized and analyzed. The fire related variables used in this research are specific elements from the NFIRS data queried using specific NFPA 901 coding. The specific elements were selected to match those elements analyzed in other studies.

The four fire variables of each state *residential fires*, *flammable liquid fires*, *water heater fires*, and *gas water heater fires* were derived from the NFIRS 1999 fire data (National Fire Protection Association, 2003). The NFIRS fire information includes all the fire incident reports to the U.S. Fire Administration by its member fire stations in the United States. Using the selected codes (National Fire Protection Association, NFPA No. 901, 1995) the data were sorted (narrowed) to the selected types of fires. In this case the first sort narrowed the entire reported fire incident to include only those fires that were residential structure fires, fire incident type 11, in homes, fixed property use codes 410-429. This sort is the *residential structure fires* variable.

The second sort of the data set, was a subset of the first sort. The second sort included only those fires of the first sort, *residential structure fires* that involved flammable liquid fires. Those fires involving flammable liquids, specifically gasoline, a Class IA flammable liquid, or a Class IB flammable liquid (type of material codes 21-23) was the type of material first ignited. The second sort was the *flammable liquid fires* variable.

The third variable was the third sort of the NFIRS data. This third sort was a subset of the second sort and included only those fires that involved water heaters as the reported ignition source of the flammable liquid fire in the residential structure. This sort used the code #12 to query out those fires involving a water heater, *water heater fires*.

The fourth and last sort was a subset of the third sort. This query used code #20 (gas) to include only those residential structure fires involving flammable liquids and gas water heaters, *gas water heater fires*.

Each of the previous fire variables was transformed into a fire rate (number of fires per 100k population). This prorating was needed to accurately compare fire incidents between states that have different populations. As stated previously, the NFIRS member fire stations report all fire incidents involving their station to the U.S. Fire Administrations. However, not all the fire stations in the country are participating members of NFIRS. The NFIRS fire data accounts for about 56% of the fire stations in the United States, thereby accounting for 56% of the estimated number of fires reported in the United States.

The U.S. Fire Administration attempted to collect a census of all the fire stations in the country (U.S. Fire Administration 2003). This census was compared to the number of fire stations reporting fires in the NFIRS data set to determine the percentage of fire departments in each state that were participating in the NFIRS program. Each state's population was multiplied by this NFIRS fire station participation percentage to derive a prorated state's population that was assumed to be covered by the participating NFIRS fire stations. This prorated state population was divided by one hundred thousand, and then divided by the fire statistic. This calculation resulted in the prorated fire incident rate for that state.

Example: *residential structure fire rate* (70.567) for state of Nebraska

$$d = \left(\frac{a}{(b * c)}\right) / 100{,}000$$

a = 1167 - the number of residential structure fires in Nebraska

b = 96.6% - the percentage of fire stations in Nebraska which participate in the NFIRS program

c = 1711263 - the State population of Nebraska

d = 70.567 - (1167 fires/(0.966*1711263))/100,000=70.567
the prorated rate of residential structure fires in Nebraska in 1999

Table 3.1 offers a listing of the variable data sets used in the current study and the origin of derivation. Two of the variable data sets, state fire rate and state climate were derived from multiple sources and manipulated as described previously, to produce the required data set. Much of the material was acquired from the internet due to the on-line availability of the U.S. governmental data and U.S. Fire Administration information. The NFIRS fire data were purchased from NFIRS for use in this study.

Table 3.1. Research data set sources

Source	State fire rate derived from multiple sources	State Population Data	State Median income data	State Education data	State Climate data	State parental status data
NFIRS fire data National Fire Protection Association (2003)	X					
Fire codes National Fire Protection Association (1995)	X					
Fire station census U.S. Fire Administration (2003)	X					
U.S. Census data U.S. Census Bureau (2000a)						X
U.S. Census data U.S. Census Bureau. (2000b)			X			
U.S. Census data U.S. Census Bureau (2000c)	X	X				
Education data Digest of Education Statistics. (2001)				X		
Heating-degree-day data National Climate Data Center (2002)					X	
Alaska Heating-degree-day data Alaska Climate Research Center (2004)					X	
Hawaii Heating-degree-day data Hawaii State Climate Office (2004)					X	

Key: X = source for that data set

The information was complied into the Statistical Package for the Social Sciences (SPSS), software for subsequent statistical analysis. The software used in this research was SPSS for Windows, Release 10.0.7 (1 June 2000), Standard version, Copyrighted SPSS.Inc.

The five variables, later defined, were analyzed in four fire groups, each representing one of the four posed research questions. Each group or data set included the independent variables *education*, *parent status*, *income*, and *climate* and one of the four dependent fire variables *residential structure fire rate*, *flammable fire rate*, *water heater fire rate*, and *gas water heater fire rate*. There were 48 tests examined involving 12 tests of each fire group. Each of the independent variables was tested as a control variable either independently or in conjunction with the other variables to determine how its (their) association with the other variables impacted the correlation tests. The four fire group variable matrix tables described later in this study will depict which variables were held as control variables in the various fire group tests and the correlation coefficients results of the test.

Definition of Variables

Climate and Socioeconomic variables

Climate: Represents the number of HDD (heating degree days) in the state for the year 1998-1999 heating season. The HDD for a particular day is a calculation of that day's average temperature subtracted from 65 degrees (F). Only positive values are used in the heating degree-day calculation. Negative values are used as part of the cooling degree-day calculation. The sum of the HDD values for the year in a given state is the average HDD value for the State. The climate data for the 48 contiguous states was reported by the National Climatic Data Center (National Climatic Data Center, 2002). The National Climate Data Center excluded Alaska and Hawaii HDD from their data set. The National Climate data also did not include a separate HDD value for the District of Columbia, because that value was included in the Maryland HDD value. This study used the Maryland HDD value for both Maryland and the District of Columbia. The state of Alaska HDD value was calculated from climate data provided by the Alaska Climate Research Center (Alaska Climate Research Center, 2004). That data included 120 weather reporting stations, primarily in urban areas, which were averaged and used as the Alaska climate variable value in this study. The state of Hawaii HDD value was calculated from climate data provided by the Hawaii State Climate Office (Hawaii State Climate Office, 2004). That data included 118 weather reporting stations, primarily in urban areas, which were averaged and used as the Hawaii climate variable value in this study.

Education: The percent of population, 25 years and older, having a high school diploma or higher in 2000, reported by National Center for Education Statistics (Digest of Education Statistics, 2001). The larger this variable, the larger percentage of that state's population of 25 years old or more that has at least a high school education.

Income: The two-year average median household income in 1998-1999 by state as reported by the United States 2000 Census (U.S. Census Bureau, 2000b).

Parent status: Household parental status as reported by the United States Census Bureau for the year 2000. The specific status is "female householder, no husband present/with own children under 18 years" (U.S. Census Bureau, 2000a). Parent status is the percentage of households in a state where the head of the household is a single parent female with children. It was calculated by dividing the number of households in a state where the head of the household is a single parent female with children by the number of households in the state as reported by the 2000 census.

Fire variables

The following definitions are presented here in logic order used in the derivation of the fire variables, not in alphabetical order, to clarify the development of the subsets.

Residential structure fire rate: Represents residential structure fires (incident type 11) in homes (fixed property use codes 410-429). This variable represents the number of residential structural fire incidents in one- and two-family dwellings and multiple-family dwellings (apartments) in a particular state divided by the state's population (incidents per 100,000 population). The population of each state was adjusted by the percentage of the fire departments involved in the NFIRS program in that state. This query excludes specific equipment involvement in the incident.

Flammable liquid fire rate: Represents the *Residential structure fire rate fires* where flammable liquids, specifically gasoline, a Class IA flammable liquid, or a Class IB flammable liquid (type of material codes 21-23) was the type of material first ignited. This query excludes specific equipment involvement in the incident.

Water heater fire rate: Represents the *Flammable liquid fire rate fires* where only water heater equipment was involved in the incident. This would include all residential water heaters regardless of their power source, i.e. natural gas water heaters, propane water heaters, electric water heaters, fuel oil water heaters. The majority of the water heaters in this group are gas water heaters.

Gas water heater fire rate: Represents the *Water heater fire rate* fires where only gas (natural and propane) water heater equipment was involved in the incident.

Limitations

This study was conducted with the following limitations.

The National Technical Information Service (NTIS) sells the raw NFIRS fire incident data for 1999 on a CD-ROM. This CD was purchased to provide the raw fire data required fire information in this research.

The household parental status variable information was acquired for the year 2000, to provide usable information but this is not for the same year for which the fire information was available. This information comes from the 2000 U.S. Census. The median household income information used in this research was the 1998-1999 two-year average income. The specific 1999 median household income information was not available. This information comes from the 2000 U.S. Census (U.S. Census Bureau, 2000b).

The number of fire departments reported by NFPA in their census report was known to exclude some departments in each state. It is not known exactly how many fire departments actually exist in each state, but the NFPA census report is the best available information. It was perceived that this report included the majority of the fire departments in each state. The number of fire departments reported in each state was used to determine the percentage of fire departments involved in NFIRS in each state. This was done to normalize the state population represented by NFIRS fire incidents in that state. Any discrepancy in the number of fire departments in a state affects the percentage of representation.

The states' HDD information was reported by the National Climatic Center (National Climatic Center, 2002). The National Climatic Center calculated the HDD for each state from the average degree day totals for each month from divisional values by weighting each division by its percentage of the total 1990 state population. Information regarding the divisions was not provided in the data source. The states 1990 population has increased during the decade preceding the 2000 census and the 1999 fire information. It is unknown how this 1990 population weight factor affected the HDD information used in this study.

Delimitations

This study was delimited by the following factors.

The NFIRS fire information used in this study was sorted into four very specific groups: residential structure fires, flammable liquid fires, water heater fires, and gas water heater fires. These groups were selected to match prior studies in order to compare the results. The specific sorting of the fire information excluded many fires and narrowed the study to a specific set of fires for the year 1999.

The variable *income* was defined as the average household income for each state used in this study as a measure of the relative affluence of households. This variable was used specifically to parallel the variable measuring the percentage of female-headed households with children. The variable female head-of-households with children is a specific type or subgroup of household as defined in the census information. To parallel or match household type with income, average household income was used. There were several other types of groupings information available but they were not considered to match with the variable *parent status*.

The variable *parent status* was defined as the percentage of a state's households for which the head of the household is described as female head of household with children. This is a specific group as defined by the 2000 Census and narrowly defines the persons that were involved in this study.

The variable *education* was defined here as the percentage of the state's population that was over 25 years of age and had attained at least a high school education. This variable gives a general view of the minimum education attained in each state. It did include people who had attained a higher level of education.

The variable *climate* was defined as the average number of HDD for each state. The National Climatic Center (National Climatic Center, 2002) calculated the average degree day totals in urban areas for each month, weighted by the percentage of the total 1990 represented by each city. This variable provides a way to describe the amount of heating that a structure will need to maintain a comfortable internal temperature in the structure. This also offers insight as to the types of structures that might be typical in a state. The construction of a given structure offers insight into the locations of appliances and possible locations where flammable liquids might be stored. The HDD information was used in this study to determine if there was a correlation between it and the number of fires in a state.

Assumptions

There were a number of assumptions made regarding the selected data sets. This study assumed the all the data sets: NFIRS fire data, Fire Administration data, education data, population data, parental status data, income data, and climate data were all collected and presented accurately. This study also made the assumption the portion of a state's fire stations that were involved in the NFIRS program provided fire protection for the same portion of the state's population used in this analysis.

CHAPTER 4. RESULTS

The aforementioned fire groups along with the socioeconomic and climate values were compiled into Table 4.1. Several of the states lacked representation or had limited representation in the 1999 NFIRS program. These states were excluded from the tables of variable values used in the calculations. Table 4.1 depicts the number of residential structure fire incidents in addition to the socioeconomic variables and climate variable. The table includes other data values not specifically included in the partial correlation calculations involved in this study, but were used in deriving the variables that were used in the final calculations. Of the 50 states and the District of Columbia, 10 states did not participate in the NFIRS program. More specifically, the states that did not participate were: Arizona, California, Delaware, Mississippi, North Carolina, North Dakota, New Mexico, Pennsylvania, Rhode Island, West Virginia. Three states, Alabama, New Hampshire, Colorado and the District of Columbia had only 1% of its fire departments involved in the NFIRS program. Alabama reported only one fire incident and no residential structure fires and was excluded from the data set. Colorado reported over 3000 fires and over 400 residential structure fires, however, because of the low population its residential structure fire rate was significantly higher than the other fire rates, thus it was also considered an outlier and excluded from the data set. Table 4.1 depicts the raw residential structure fire data and the socioeconomic and climate data used in this study to derive the data sets and the data set themselves.

The following histograms are graphic descriptions of the dependent variables *residential structure fire rate*, *flammable liquid fire rate*, *water heater fire rate*, and *gas*

Table 4.1. Residential structure fire with socioeconomic and climate values (1999)

State	Fire Dept Census	Fire Dept NFIRS	Pct in program	No. of Inc.	Res. Structure. Fires	Residential fire rate	Res. Flammmable liquid. Fires
AK	103	98	0.951	4315	664	111.316	5
AL	461	1	0.002	1	0	0.000	0
AR	466	422	0.905	43035	2171	89.674	18
AZ	190	0	0.000	0	0	0.000	0
CA	683	0	0.000	0	0	0.000	0
CO	254	1	0.003	3067	479	2828.612	8
CT	223	242	1.000	17223	3162	92.848	20
DC	2	1	0.500	101471	558	195.084	9
DE	32	0	0.000	0	0	0.000	0
FL	425	2	0.004	25977	286	380.262	3
GA	361	97	0.268	20828	4457	202.620	49
HI	11	2	0.181	1898	259	117.577	2
IA	481	526	1.000	13040	2027	69.267	16
ID	140	131	0.935	27840	860	71.029	5
IL	927	845	0.911	60258	10056	88.828	135
IN	579	3	0.005	183	3	9.522	0
KS	356	532	1.000	146146	2936	109.209	58
KY	474	529	1.000	65431	3114	77.045	22
LA	275	129	0.469	8933	1840	87.771	18
MA	310	329	1.000	28971	7713	604.977	31
MD	198	322	1.000	21702	4960	93.647	35
ME	241	40	0.166	17570	257	24.388	0
MI	730	827	1.000	180745	4570	45.983	42
MN	521	658	1.000	150147	3192	64.884	29
MO	524	18	0.034	319	13	6.763	1
MS	279	0	0.000	0	0	0.000	0
MT	200	18	0.090	1614	20	24.631	0
NC	749	0	0.000	0	0	0.000	0
ND	198	0	0.000	0	0	0.000	0
NE	238	230	0.966	26627	1167	70.567	18
NH	166	1	0.006	42	0	0.000	0
NJ	562	329	0.585	208740	5791	117.563	29
NM	186	0	0.000	0	0	0.000	0
NV	60	17	0.283	16722	172	30.379	54
NY	1191	1386	1.000	34972	7011	36.945	0
OH	956	1105	1.000	63471	14518	127.876	123
OK	468	72	0.153	13462	2672	503.324	42
OR	238	270	1.000	75404	2399	70.117	31
PA	1368	0	0.000	0	0	0.000	0
RI	68	0	0.000	0	0	0.000	0
SC	259	144	0.556	9289	1827	81.905	11
SD	219	208	0.949	3305	449	62.628	9
TN	410	197	0.480	86077	3659	133.851	34
TX	991	555	0.560	738334	13924	119.234	260
UT	138	151	1.000	48277	1103	49.391	16
VA	361	338	0.936	20970	4909	74.069	29
VT	142	109	0.767	19167	530	113.408	5
WA	373	60	0.160	41622	846	89.229	9
WI	602	169	0.280	18947	1559	103.536	13
WV	283	0	0.000	0	0	0.000	0
WY	84	91	1.000	2515	289	58.527	2

Table 4.1. (Continued).

State	Flammable liquid fire rate	Res. Flam. Fires. w/w.h.	Water heater fire rate	Res. Flam. Fires. w/gwh	Gas water heater fire rate	Education
AK	0.838	0	0.000	0	0.000	90.4
AL	0.000	0	0.000	0	0.000	77.5
AR	0.743	4	0.165	1	0.041	81.7
AZ	0.000	0	0.000	0	0.000	85.1
CA	0.000	0	0.000	0	0.000	81.2
CO	47.242	2	11.810	2	11.810	89.7
CT	0.587	0	0.000	0	0.000	88.2
DC	3.146	1	0.349	0	0.000	83.2
DE	0.000	0	0.000	0	0.000	86.1
FL	3.988	1	1.329	1	1.329	84.0
GA	2.227	8	0.363	6	0.272	82.6
HI	0.907	0	0.000	0	0.000	87.4
IA	0.546	3	0.102	2	0.068	89.7
ID	0.413	0	0.000	0	0.000	86.2
IL	1.192	10	0.088	5	0.044	85.5
IN	0.000	0	0.000	0	0.000	84.6
KS	2.157	5	0.186	4	0.148	88.1
KY	0.544	5	0.123	2	0.049	78.7
LA	0.858	5	0.238	4	0.190	80.8
MA	2.431	1	0.078	1	0.078	89.3
MD	0.660	6	0.113	6	0.113	85.7
ME	0.000	0	0.000	0	0.000	85.1
MI	0.422	3	0.030	3	0.030	86.2
MN	0.589	3	0.061	2	0.040	90.8
MO	0.520	0	0.000	0	0.000	86.6
MS	0.000	0	0.000	0	0.000	80.3
MT	0.000	0	0.000	0	0.000	89.6
NC	0.000	0	0.000	0	0.000	79.2
ND	0.000	0	0.000	0	0.000	85.5
NE	1.088	3	0.181	3	0.181	90.4
NH	0.000	0	0.000	0	0.000	88.1
NJ	0.588	3	0.060	1	0.020	87.3
NM	0.000	0	0.000	0	0.000	82.2
NV	9.537	0	0.000	0	0.000	82.8
NY	0.000	6	0.031	5	0.026	82.5
OH	1.083	14	0.123	14	0.123	87.0
OK	7.911	5	0.941	3	0.565	86.1
OR	0.906	0	0.000	0	0.000	88.1
PA	0.000	0	0.000	0	0.000	85.7
RI	0.000	0	0.000	0	0.000	81.3
SC	0.493	2	0.089	2	0.089	83.0
SD	1.255	1	0.139	1	0.139	91.8
TN	1.243	2	0.073	2	0.073	79.9
TX	2.226	44	0.376	36	0.308	79.2
UT	0.716	1	0.044	1	0.044	90.7
VA	0.437	3	0.045	2	0.030	86.6
VT	1.069	0	0.000	0	0.000	90.0
WA	0.949	0	0.000	0	0.000	91.8
WI	0.863	1	0.066	1	0.066	86.7
WV	0.000	0	0.000	0	0.000	77.1
WY	0.405	0	0.000	0	0.000	90.0

Table 4.1. (Continued).

State	State pop	Adj. Pop w/fire department.	Total Households	Households w/fem head	Parent status	Income	Climate
AK	626932	596498	221600	17243	0.077	51993	11699
AL	4447100	9646	1737080	141057	0.081	35267	2279
AR	2673400	2420975	1042696	76774	0.073	30527	2927
AZ	5130632	0	1901327	129511	0.068	39911	1929
CA	33871648	0	11502870	834716	0.072	46008	2845
CO	4301261	16934	1658238	102113	0.061	49238	6680
CT	3405565	3405565	1301670	91114	0.070	51432	5599
DC	572059	286029	248338	24561	0.098	39363	4254
DE	783600	0	298736	22975	0.076	49283	4303
FL	15982378	75211	6337929	437680	0.069	37540	506
GA	8186453	2199684	3006369	258006	0.085	41822	2329
HI	1211537	220279	403240	23619	0.058	46945	51
IA	2926324	2926324	1149276	64367	0.056	42808	6220
ID	1293953	1210770	469645	27091	0.057	37287	6640
IL	12419293	11320714	4591779	315957	0.068	47193	5559
IN	6080485	31505	2336306	160311	0.068	41010	5307
KS	2688418	2688418	1037891	62757	0.060	38220	4428
KY	4041769	4041769	1590647	110565	0.069	36113	3985
LA	4468976	2096356	1656053	161546	0.097	32006	1322
MA	1274923	1274923	518200	32352	0.062	40918	5706
MD	5296486	5296486	1980859	159342	0.080	52881	4254
ME	6349097	1053792	2443580	163550	0.066	46312	7390
MI	9938444	9938444	3785661	283758	0.075	46986	6153
MN	4919479	4919479	1895127	111371	0.058	49846	7564
MO	5595211	192201	2194594	156571	0.071	45160	4604
MS	2844658	0	1046434	106203	0.101	32581	1996
MT	902195	81197	358667	21201	0.059	32169	7394
NC	8049313	0	3132013	227351	0.072	38712	3078
ND	642200	0	257152	13639	0.053	34665	8601
NE	1711263	1653741	666184	39685	0.059	39332	5741
NH	1235786	7444	474606	27257	0.057	48323	6833
NJ	8414350	4925838	3064645	196809	0.064	51320	4954
NM	1819046	0	677971	56133	0.082	34410	4190
NV	1998257	566172	751165	50675	0.067	43918	3983
NY	18976457	18976457	7056860	573384	0.081	41504	5331
OH	11353140	11353140	4445773	323095	0.072	42421	5384
OK	3450654	530869	1342293	94403	0.070	33235	3157
OR	3421399	3421399	1333723	83131	0.062	42260	5206
PA	12281054	0	4777003	298021	0.062	41507	5422
RI	1048319	0	408424	31703	0.077	43676	5207
SC	4012012	2230616	1533854	131010	0.085	37455	2355
SD	754844	716929	290245	17645	0.060	36681	6825
TN	5689283	2733631	2232905	165842	0.074	35824	3445
TX	20851820	11677860	7393354	564288	0.076	40065	1569
UT	2233169	2233169	701281	40329	0.0575	46436	5864
VA	7078515	6627529	2699173	186591	0.069	48678	4051
VT	608827	467339	240634	14792	0.061	40589	7449
WA	5894121	948115	2271398	146920	0.064	44598	5383
WI	5363675	1505749	2084544	128952	0.061	46357	6763
WV	1808344	0	736481	42304	0.057	29737	4928
WY	493782	493782	193608	11604	0.059	38839	7513

water heater fire rate, respectively. These figures depict very skewed bell curves indicative of values that are not normally distributed. The histograms are a plot of the frequency of the variable and the residuals of that variable. The residuals are the "standardized" difference between the predicted value of this variable and the actual value. These plots were derived from the linear regression SPSS output and were used to visually examine the plots for outliers. The data used to produce the histograms in Figures 4.1 – 4.4 are derived from information from Table 4.2. Table 4.2 depicts only those states which had fire departments which participated in the NFIRS program and were not considered outliers. Table 4.2 also depicts the participating states and their respective residential structure fire data and the socioeconomic and climate data.

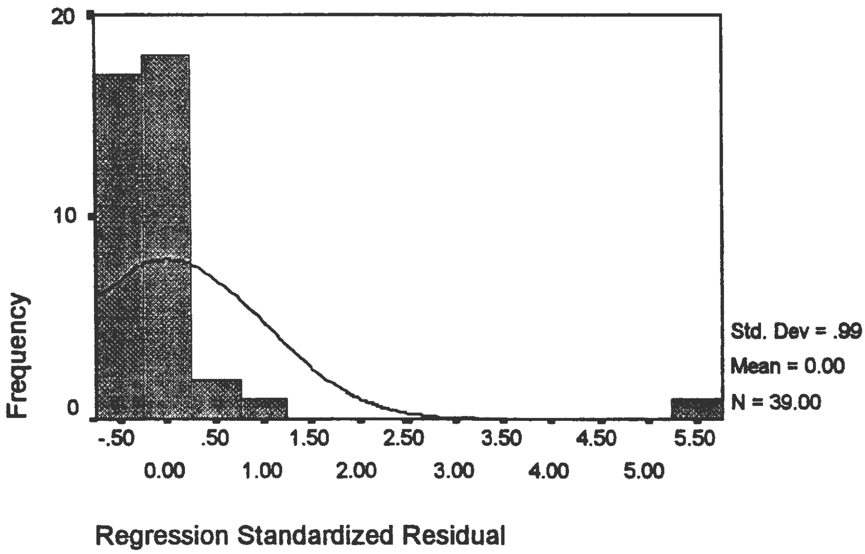

Figure 4.1. Histogram of the *residential structure fire rate* variable from Table 4.2

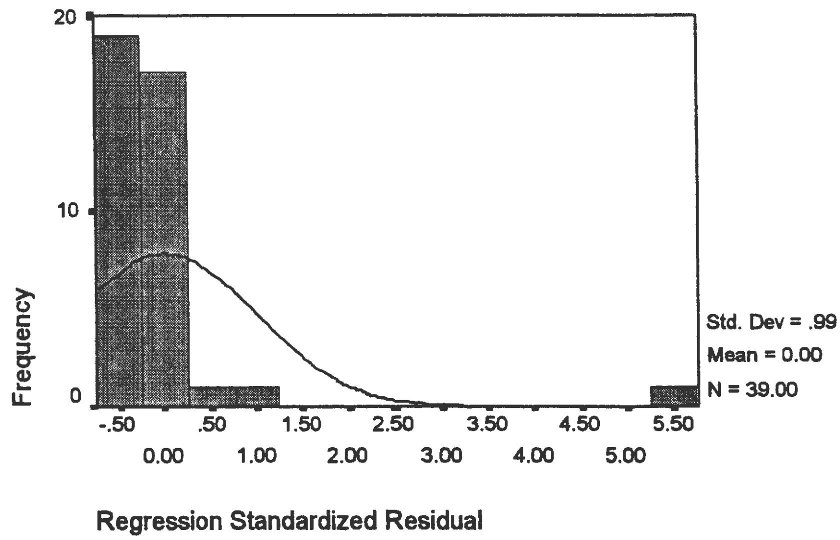

Figure 4.2. Histogram of the *flammable liquid fire rate* variable from Table 4.2

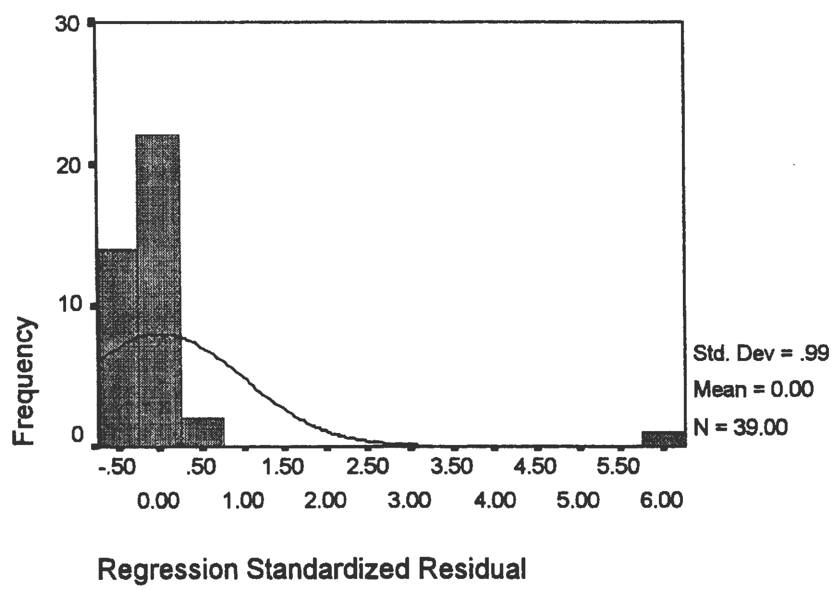

Figure 4.3. Histogram of the *water heater fire rate* variable from Table 4.2

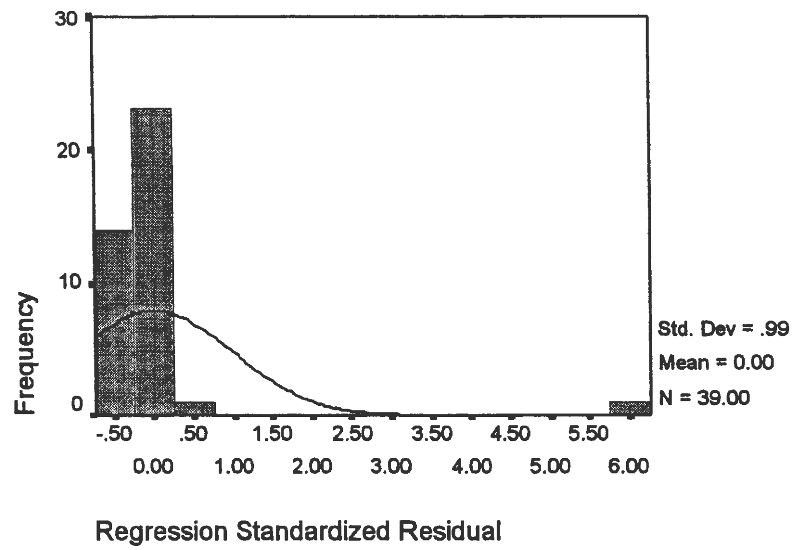

Figure 4.4. Histogram of the *gas water heater fire rate* variable from Table 4.2

Residential Structure Fire Group

In an effort to improve the normality of the fire variables involved in the residential structure fire group, several outlier states were excluded. Five states were excluded from Table 4.2 for use in the *residential structure fire rate* variable calculations of this study: Alabama, Florida, Massachusetts, New Hampshire, and Oklahoma. These states were excluded because they either had no representation or contained data values that were deemed outliers. The reason for the values being outliers is unknown, but such reasons might include: coding errors which might include typing errors, transfer errors, misinterpretation of the code or, possibly, inaccurate reporting of the facts of the fire. The normality of the fire variables was improved and is described in the histograms depicted later in this chapter.

Table 4.3 lists residential structure fire group data from each of the states regarding: fire rate, education attainment percentage, parental status percentage, household income, and state climate involved in the correlation calculation.

Table 4.2. Residential structure fire with socioeconomic and climate values (1999) of states participating in the NFIRS program

State	Fire Dept Cen	Fire Dept NFIRS	Pct in prog	No. of Inc.	Res. Struc.Fires	Residential fire rate	Res. Flam/liq. Fires	Flammable liquid fire rate	Res. Flam. Fires. w/w.h.	Water heater fire rate
AK	103	98	0.951	4315	664	111.316	5	0.838	0	0.000
AL	461	1	0.002	1	0	0.000	0	0.000	0	0.000
AR	466	422	0.905	43035	2171	89.674	18	0.743	4	0.165
CT	223	242	1.000	17223	3162	92.848	20	0.587	0	0.000
DC	2	1	0.500	101471	558	195.084	9	3.146	1	0.349
FL	425	2	0.004	25977	286	380.262	3	3.988	1	1.329
GA	361	97	0.268	20828	4457	202.620	49	2.227	8	0.363
HI	11	2	0.181	1898	259	117.577	2	0.907	0	0.000
IA	481	526	1.000	13040	2027	69.267	16	0.546	3	0.102
ID	140	131	0.935	27840	860	71.029	5	0.413	0	0.000
IL	927	845	0.911	60258	10056	88.823	135	1.192	10	0.088
IN	579	3	0.005	183	3	9.522	0	0.000	0	0.000
KS	356	532	1.000	146146	2936	109.209	58	2.157	5	0.186
KY	474	529	1.000	65431	3114	77.045	22	0.544	5	0.123
LA	275	129	0.469	8933	1840	87.771	18	0.858	5	0.238
MA	310	329	1.000	28971	7713	604.977	31	2.431	1	0.078
MD	198	322	1.000	21702	4960	93.647	35	0.660	6	0.113
ME	241	40	0.166	17570	257	24.388	0	0.000	0	0.000
MI	730	827	1.000	180745	4570	45.983	42	0.422	3	0.030
MN	521	658	1.000	150147	3192	64.884	29	0.589	3	0.061
MO	524	18	0.034	319	13	6.763	1	0.520	0	0.000
MT	200	18	0.090	1614	20	24.631	0	0.000	0	0.000
NE	238	230	0.966	26627	1167	70.567	18	1.088	3	0.181
NH	166	1	0.006	42	0	0.000	0	0.000	0	0.000
NJ	562	329	0.585	208740	5791	117.563	29	0.588	3	0.060
NV	60	17	0.283	16722	172	30.379	54	9.537	0	0.000
NY	1191	1386	1.000	34972	7011	36.945	0	0.000	6	0.031
OH	956	1105	1.000	63471	14518	127.876	123	1.083	14	0.123
OK	468	72	0.153	13462	2672	503.324	42	7.911	5	0.941
OR	238	270	1.000	75404	2399	70.117	31	0.906	0	0.000
SC	259	144	0.556	9289	1827	81.905	11	0.493	2	0.089
SD	219	208	0.949	3305	449	62.628	9	1.255	1	0.139
TN	410	197	0.480	86077	3659	133.851	34	1.243	2	0.073
TX	991	555	0.560	738334	13924	119.234	260	2.226	44	0.376
UT	138	151	1.000	48277	1103	49.391	16	0.716	1	0.044
VA	361	338	0.936	20970	4909	74.069	29	0.437	3	0.045
VT	142	109	0.767	19167	530	113.408	5	1.069	0	0.000
WA	373	60	0.160	41622	846	89.229	9	0.949	0	0.000
WI	602	169	0.280	18947	1559	103.536	13	0.863	1	0.066
WY	84	91	1.000	2515	289	58.527	2	0.405	0	0.000

Table 4.2. (Continued).

State	Res. Flam. Fires. w/gwh	Gas water heater fire rate	Education	St.pop	Adj. Pop-fire depart.	To.No. House	No. House w/fem head	Parent status	Income	Climate
AK	0	0.000	90.4	626932	596498	221600	17243	0.077	51993	11699
AR	1	0.041	81.7	2673400	2420975	1042696	76774	0.073	30527	2927
CT	0	0.000	88.2	3405565	3405565	1301670	91114	0.070	51432	5599
DC	0	0.000	83.2	572059	286029	248338	24561	0.098	39363	4254
FL	1	1.329	84.0	15982378	75211	6337929	437680	0.069	37540	506
GA	6	0.272	82.6	8186453	2199684	3006369	258006	0.085	41822	2329
HI	0	0.000	87.4	1211537	220279	403240	23619	0.058	46945	51
IA	2	0.068	89.7	2926324	2926324	1149276	64367	0.056	42808	6220
ID	0	0.000	86.2	1293953	1210770	469645	27091	0.057	37287	6640
IL	5	0.044	85.5	12419293	11320714	4591779	315957	0.068	47193	5559
IN	0	0.000	84.6	6080485	31505	2336306	160311	0.068	41010	5307
KS	4	0.148	88.1	2688418	2688418	1037891	62757	0.060	38220	4428
KY	2	0.049	78.7	4041769	4041769	1590647	110565	0.069	36113	3985
LA	4	0.190	80.8	4468976	2096356	1656053	161546	0.097	32006	1322
MA	1	0.078	89.3	1274923	1274923	518200	32352	0.062	40918	5706
MD	6	0.113	85.7	5296486	5296486	1980859	159342	0.080	52881	4254
ME	0	0.000	85.1	6349097	1053792	2443580	163550	0.066	46312	7390
MI	3	0.030	86.2	9938444	9938444	3785661	283758	0.075	46986	6153
MN	2	0.040	90.8	4919479	4919479	1895127	111371	0.058	49846	7564
MO	0	0.000	86.6	5595211	192201	2194594	156571	0.071	45160	4604
MT	0	0.000	89.6	902195	81197	358667	21201	0.059	32169	7394
NE	3	0.181	90.4	1711263	1653741	666184	39685	0.059	39332	5741
NH	0	0.000	88.1	1235786	7444	474606	27257	0.057	48323	6833
NJ	1	0.020	87.3	8414350	4925838	3064645	196809	0.064	51320	4954
NV	0	0.000	82.8	1998257	566172	751165	50675	0.067	43918	3983
NY	5	0.026	82.5	18976457	18976457	7056860	573384	0.081	41504	5331
OH	14	0.123	87.0	11353140	11353140	4445773	323095	0.072	42421	5384
OK	3	0.565	86.1	3450654	530869	1342293	94403	0.070	33235	3157
OR	0	0.000	88.1	3421399	3421399	1333723	83131	0.062	42260	5206
SC	2	0.089	83.0	4012012	2230616	1533854	131010	0.085	37455	2355
SD	1	0.139	91.8	754844	716929	290245	17645	0.060	36681	6825
TN	2	0.073	79.9	5689283	2733631	2232905	165842	0.074	35824	3445
TX	36	0.308	79.2	20851820	11677860	7393354	564288	0.076	40065	1569
UT	1	0.044	90.7	2233169	2233169	701281	40329	0.057	46436	5864
VA	2	0.030	86.6	7078515	6627529	2699173	186591	0.069	48678	4051
VT	0	0.000	90.0	608827	467339	240634	14792	0.061	40589	7449
WA	0	0.000	91.8	5894121	948115	2271398	146920	0.064	44598	5383
WI	1	0.066	86.7	5363675	1505749	2084544	128952	0.061	46357	6763
WY	0	0.000	90.0	493782	493782	193608	11604	0.059	38839	7513

It compares the *residential structure fire rate* variable with socioeconomic values and climate values.

Figure 4.5 depicts the histogram which describes the dependent variable *residential structure fire rate* used in the residential structure fire group partial correlations calculations. This histogram depicts the variable after the outlier states were removed from the original data set depicted in Table 4.2. The normality improved when comparing Figure 4.1 and Figure 4.5.

Table 4.4 depicts the matrix of variables used in the residential structure fire group partial correlations. The calculations involved controlling a variable or variables in each calculation. Table 4.4 indicates which variables were used as controls in the various tabulations. The dependent variable *residential structure fire rate* and the four independent variables *education*, *parent status*, *income*, and *climate* were used in each calculation This table also depicts the correlation coefficient results of the calculations, and the related p-values. The bolded results indicate the variables which correlated with residential structure fire rate at test of significance tests of $p \leq .05$. In 6 of the 12 tests, the variable *parent status* exhibited a positive correlation with the variable *residential structure fire rate*, as predicted in the literature. This is interpreted as meaning as the percentage of households which have head-of-household as a female with children at home in a particular state increase the number of residential structure fires, also increases.

This group analysis tested these variables 12 times and found 6 significant correlations. Considering a Bonferroni Test (George & Mallery, 2001) to adjust for experiment-wise error the p-value (0.05) was divided by the number of tests performed (12) providing a rigorous test.

Table 4.3. Residential structure fire group with socioeconomic values and climate values

State	Residential fire rate	Education	Parent status	Income	Climate
AK	111.316	90.4	0.077	51993	11699
AR	89.675	81.7	0.074	30527	2924
CT	92.848	88.2	0.070	51432	5599
DC	195.084	83.2	0.098	39363	4245
GA	202.620	82.6	0.086	41822	2329
HI	117.577	87.4	0.058	46945	51
IA	69.268	89.7	0.056	42808	6220
ID	71.029	86.2	0.058	37287	6640
IL	88.828	85.5	0.069	47193	5559
IN	9.522	84.6	0.069	41010	5307
KS	109.209	88.1	0.060	38220	4428
KY	77.045	78.7	0.070	36113	3985
LA	87.771	80.8	0.098	32006	1322
MD	93.647	85.7	0.080	52881	4254
ME	24.388	85.1	0.067	46312	5706
MI	45.983	86.2	0.075	46986	6153
MN	64.885	90.8	0.059	49846	7564
MO	6.764	86.6	0.071	45160	4604
MT	24.631	89.6	0.059	32169	7394
NE	70.567	90.4	0.060	39332	5741
NJ	117.564	87.3	0.064	51320	4954
NV	30.379	82.8	0.067	43918	3983
NY	36.946	82.5	0.081	41504	5331
OH	127.877	87.0	0.073	42421	5384
OR	70.118	88.1	0.062	42260	5206
SC	81.906	83.0	0.085	37455	2355
SD	62.628	91.8	0.061	36681	6825
TN	133.851	79.9	0.074	35824	3445
TX	119.234	79.2	0.076	40065	1569
UT	49.392	90.7	0.058	46436	5864
VA	74.070	86.6	0.069	48678	4051
VT	113.408	90.0	0.061	40589	7449
WA	89.230	91.8	0.065	44598	5383
WI	103.536	86.7	0.062	46357	6763
WY	58.528	90.0	0.060	38839	7513

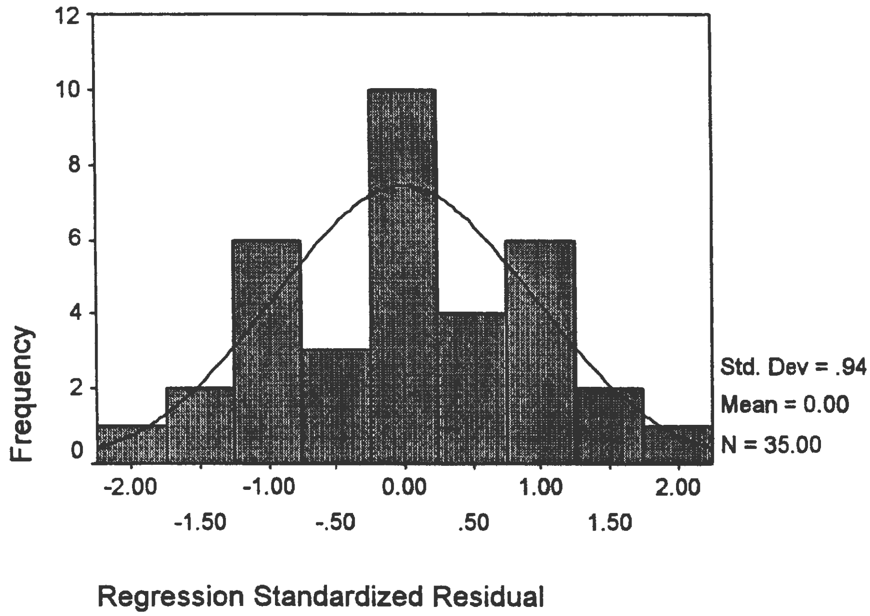

Figure 4.5. Histogram of the *residential structure fire rate* variable with outliers removed

In this case the threshold for significance is lowered to 0.004 (0.05/12=0.004). When using this more rigorous p-value, none of the tests in this group exhibited a significant correlation. The Bonferroni Test is used when there are 20 or more tests of the same variables used in that analysis to ensure significance is determined correctly. In this case there were only 12 tests in this fire group using the same variables and therefore the Bonferroni Test is not going to be used here to determine the p value of significance. It was assumed that no additional significant correlations could be found due to the low number of data values available in this study. On the other hand, the literature predicted significant correlations between the variables *education, income* and *climate* and the number of fires.

Table 4.4. Variable matrix and correlation coefficient results for residential structure fire group

Tests	education	Parent status	income	climate
test 1	variable	variable	variable	control
correlation	-0.0397	**0.3459**	0.0829	
significance	0.823	**0.045**	0.641	
test 2	variable	variable	control	variable
correlation	-0.2258	**0.4192**		-0.2883
significance	0.199	**0.014**		0.098
test 3	variable	control	variable	variable
correlation	0.0764		0.0648	-0.1346
significance	0.668		0.716	0.448
test 4	control	variable	variable	variable
correlation		**0.3728**	0.0841	-0.1887
significance		**0.030**	0.636	0.285
test 5	variable	control	control	control
correlation	0.1667			
significance	0.362			
test 6	control	variable	control	control
correlation		**0.3790**		
significance		**0.032**		
test 7	control	control	variable	control
correlation			0.0523	
significance			0.776	
test 8	control	control	control	variable
correlation				-0.2193
significance				0.228
test 9	control	control	variable	variable
correlation			0.0403	-0.2169
significance			0.824	0.225
test 10	variable	variable	control	control
correlation	-0.0628	**0.3502**		
significance	0.729	**0.046**		
test 11	variable	control	control	variable
correlation	0.0571			-0.1552
significance	0.752			0.389
test 12	control	variable	variable	control
correlation		**0.3863**	0.0960	
significance		**0.026**	0.595	

Note: Bolded values depict a significant correlation with residential structure fire rate at $p \leq .05$ using a two-tailed test.

Example: test 2 – *education, parent status, income* and *climate* were all included in the partial correlation. *Income* was the control variable. The effect of *income* was fixed and the resulting correlation coefficients of the other variables reflect their effect only. Comparing test 1 and test 2 the coefficients of *education* and *parent status* grew stronger when income was fixed, meaning *income* does not have a strong association here.

Flammable Liquid Fire Group

In an effort to improve the normality of the *flammable liquid fire group* variables, several outlier states were excluded. Six states were excluded from Table 4.2 for use in the *flammable liquid fire rate* variable calculations of this study: Alabama, Florida, Massachusetts, New Hampshire, Nevada and Oklahoma. These states were excluded because they either had no representation or contained data values that were deemed outliers. The reason for the values being outliers is unknown, but reasons might include coding errors which might include typing errors, transfer errors, misinterpretation of the code and missing data. The normality of the fire variables was improved and is described in the histograms depicted later in this study.

Table 4.5 lists the *flammable liquid fire group* data for each of the states after outliers were removed: *fire*, *education*, *parental status*, *income*, and *climate* which were involved in this correlation calculation.

Figure 4.6 depicts the histogram of *flammable liquid fire rate* after outliers were removed. As shown, the normality improved when comparing Figure 4.2 and Figure 4.6.

Table 4.6 depicts the matrix of variables used in the flammable liquid fire group partial correlations. The calculations involved controlling variable or variables in each calculation. Table 4.6 depicts which variables were used as controls in the various tabulations. The dependent variable *flammable liquid fire rate* and the four independent variables, *education*, *parent status*, *income*, and *climate*, were used in each calculation. This table also depicts the results of the calculations, and the correlation coefficient values and its significance. The bolded results indicate significant correlations with the *flammable liquid fire group* at $p \leq .05$.

Table 4.5. Flammable liquid fire group with socioeconomic and climate values

State	Flammable liquid fire rate	Education	Parent status	Income	Climate
AK	0.838	90.4	0.077	51993	11699
AR	0.743	81.7	0.073	30527	2927
CT	0.587	88.2	0.070	51432	5599
DC	3.146	83.2	0.098	39363	4245
GA	2.227	82.6	0.085	41822	2329
HI	0.907	87.4	0.058	46945	51
IA	0.546	89.7	0.056	42808	6220
ID	0.413	86.2	0.057	37287	6640
IL	1.192	85.5	0.068	47193	5559
IN	0	84.6	0.068	41010	5307
KS	2.157	88.1	0.060	38220	4428
KY	0.544	78.7	0.069	36113	3985
LA	0.858	80.8	0.097	32006	1322
MD	0.660	85.7	0.080	52881	4254
ME	0	85.1	0.066	46312	5706
MI	0.422	86.2	0.075	46986	6153
MN	0.589	90.8	0.058	49846	7564
MO	0.520	86.6	0.071	45160	4604
MT	0	89.6	0.059	32169	7394
NE	1.088	90.4	0.059	39332	5741
NJ	0.588	87.3	0.064	51320	4954
NY	0	82.5	0.081	41504	5331
OH	1.083	87.0	0.072	42421	5384
OR	0.906	88.1	0.062	42260	5206
SC	0.493	83.0	0.085	37455	2355
SD	1.255	91.8	0.060	36681	6825
TN	1.243	79.9	0.074	35824	3445
TX	2.226	79.2	0.076	40065	1569
UT	0.716	90.7	0.057	46436	5864
VA	0.437	86.6	0.069	48678	4051
VT	1.069	90.0	0.061	40589	7449
WA	0.949	91.8	0.064	44598	5383
WI	0.863	86.7	0.061	46357	6763
WY	0.405	90.0	0.059	38839	7513

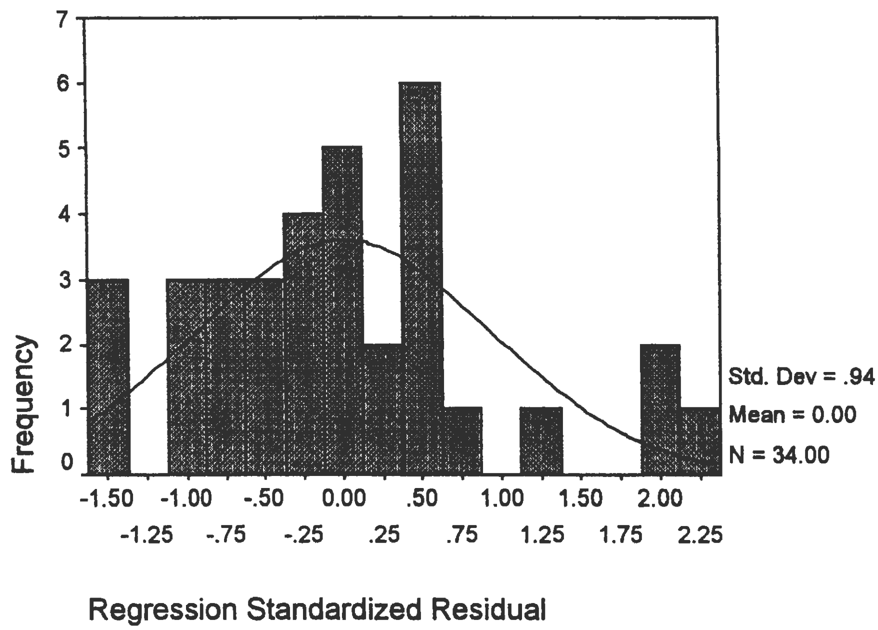

Figure 4.6. Histogram of *Flammable liquid fire rate* after outliers were removed

As depicted in Table 4.6 the bolded cells indicate those variables that correlated significantly ($p \leq .05$).

In one of the 12 tests, the variable *parent status* exhibited a positive correlation with the variable *flammable liquid fire rate,* as predicted in the literature. This is interpreted as meaning as the percentage of households which have head-of-household as a female with children at home in a particular state increase the number of residential structure fires, also increases. This group analysis tested these variables 12 times and found one significant correlation. Considering a Bonferroni Test (George & Mallery, 2001) to adjust for experiment-wise error the p-value (0.05) was divided by the number of tests performed (12) providing a rigorous test. In this case the threshold for significance is lowered to 0.004 (0.05/12=0.004). Using this more rigorous p-value, none of the tests of this group exhibited a significant correlation. The Bonferroni Test is used when there are 20 or more tests of the same variables used in that analysis to ensure significance is determined correctly. In this case there were only 12 tests in this fire group using the same variables and therefore the Bonferroni Test is not going to be used here to determine the p value of significance. When the effect of the variable *income* was removed in the calculation, the effect of *parent status* was significant.

In this case, about 17% of the increase in *residential structure fire rate* was the association of *parental status*. However, considering the Bonferroni Test (George & Mallery, 2001), no variables were exhibited to be significant.

It was assumed that no significant correlations could be found due to the low number of data values available in this study. On the other hand, the literature predicted significant correlations between the variables *education*, *climate* and *income* and the number of fires. However, no significant correlation was found in this study.

Water Heater Fire Group

In an effort to improve the normality of the *water heater fire group* variables, several outlier states were excluded. Seven states and the District of Columbia were excluded from Table 4.2 for use in the *water heater fire group* calculations of this study: Alabama, District of Columbia, Florida, Georgia, Massachusetts, New Hampshire, Nevada, and Oklahoma. These states were excluded because they either had no representation or contained data values that were deemed outliers. The reason for the values being outliers is unknown, but reasons might include coding errors which might include typing errors, transfer errors, or misinterpretation of the code. The normality of the fire variables was improved and is described in the histograms depicted later in this study.

Table 4.7 lists the *water heater fire group* data for the states: *fire rate*, *education*, *parental status*, *income*, and *climate* involved in this correlation. Comparing Figure 4.3 with Figure 4.7 shows the improvement in normality after the outliers were removed.

Table 4.8 depicts the matrix of variables used in the water heater fire group partial correlations.

Figure 4.7 depicts the histogram of *water heater fire rate* after outliers were removed. The calculations involved controlling variable or variables in each calculation. Table 4.8 shows which variables were used as controls in the various tabulations.

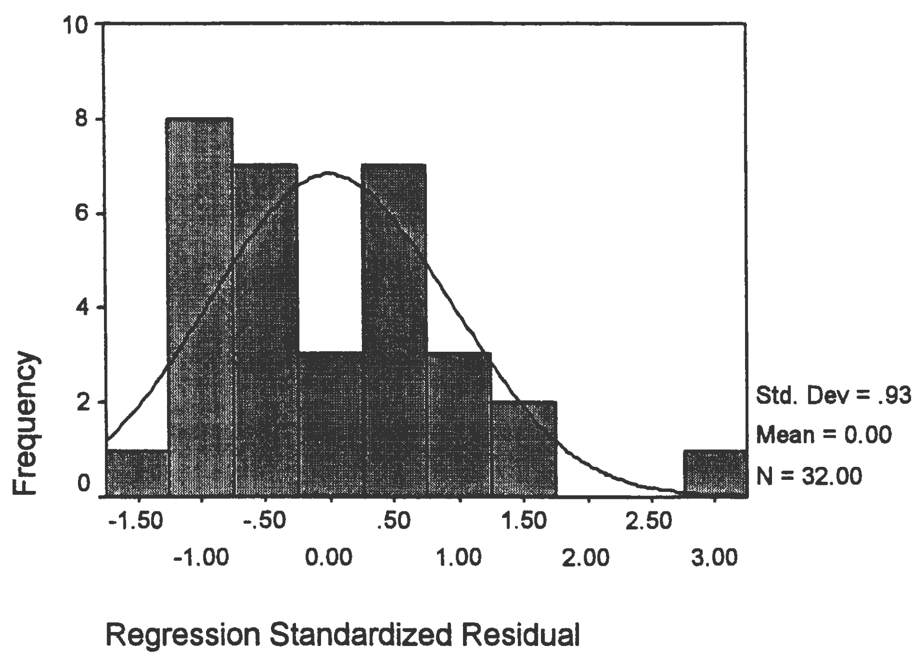

Figure 4.7. Histogram of *water heater fire rate* after outliers were removed

Table 4.6. Variable matrix and correlation coefficient results for the flammable liquid fire group

Tests	education	parent status	income	climate
test 13	variable	variable	variable	control
correlation	-0.0065	0.2765	-0.0638	
significance	0.971	0.119	0.724	
test 14	variable	variable	control	variable
correlation	-0.1493	**0.3490**		-0.2732
significance	0.407	**0.047**		0.124
test 15	variable	control	variable	variable
correlation	0.0635		-0.0998	-0.1805
significance	0.726		0.580	0.315
test 16	control	variable	variable	variable
correlation		0.3192	-0.0779	-0.2355
significance		0.070	0.667	0.187
test 17	variable	control	control	control
correlation	0.2305			
significance	0.212			
test 18	control	variable	control	control
correlation		0.3527		
significance		0.052		
test 19	control	control	variable	control
correlation			-0.1266	
significance			0.497	
test 20	control	control	control	variable
correlation				-0.2581
significance				0.161
test 21	control	control	variable	variable
correlation			-0.1340	-0.2616
significance			0.465	0.148
test 22	variable	variable	control	control
correlation	0.0243	0.2753		
significance	0.895	0.127		
test 23	variable	control	control	variable
correlation	0.1099			-0.1616
significance	0.549			0.377
test 24	control	variable	variable	control
correlation		0.3380	-0.0679	
significance		0.095	0.712	

Note: Bolded values depict a significant correlation with *flammable liquid fire rate* at $p \leq .05$ using a two-tailed test.

Example: test 14 – *education, parent status, income* and *climate* were all included in the partial correlation. *Income* was the control variable. The effect of *income* was fixed and the resulting correlation coefficients of the other variables reflect their effect only. Comparing test 13 and test 14 the coefficients of *education* and *parent status* grew stronger when *income* was fixed, meaning *income* does not have a strong association here.

Table 4.7. Water heater fire group with socioeconomic and climate values

State	Water heater fire rate	Education	Parent status	Income	Climate
AK	0	90.4	0.077	51993	11699
AR	0.165	81.7	0.073	30527	2927
CT	0	88.2	0.070	51432	5599
HI	0	87.4	0.058	46945	51
IA	0.102	89.7	0.056	42808	6220
ID	0	86.2	0.057	37287	6640
IL	0.088	85.5	0.068	47193	5559
IN	0	84.6	0.068	41010	5307
KS	0.186	88.1	0.060	38220	4428
KY	0.123	78.7	0.069	36113	3985
LA	0.238	80.8	0.097	32006	1322
MD	0.113	85.7	0.080	52881	4254
ME	0	85.1	0.066	46312	5706
MI	0.030	86.2	0.075	46986	6153
MN	0.061	90.8	0.058	49846	7564
MO	0	86.6	0.071	45160	4604
MT	0	89.6	0.059	32169	7394
NE	0.181	90.4	0.059	39332	5741
NJ	0.060	87.3	0.064	51320	4954
NY	0.031	82.5	0.081	41504	5331
OH	0.123	87.0	0.072	42421	5384
OR	0	88.1	0.062	42260	5206
SC	0.089	83.0	0.085	37455	2355
SD	0.139	91.8	0.060	36681	6825
TN	0.073	79.9	0.074	35824	3445
TX	0.376	79.2	0.076	40065	1569
UT	0.044	90.7	0.057	46436	5864
VA	0.045	86.6	0.069	48678	4051
VT	0	90.0	0.061	40589	7449
WA	0	91.8	0.064	44598	5383
WI	0.066	86.7	0.061	46357	6763
WY	0	90.0	0.059	38839	7513

The dependent variable *water heater fire rate* and the four independent variables, *education*, *parent status*, *income*, and *climate*, were used in each calculation. This table also depicts the results of the calculations, and the correlation coefficient values and the significance. The bolded results are results that correlate significantly.

As depicted in Table 4.8, the bolded cells indicate those variables which appear to correlate significantly at $p \leq .05$. In two of the 12 tests, the variable *education* and *climate* negatively correlated to the variable *water heater fire rate*. This was interpreted as meaning as the state's average high school education rate increases and the state's average number of heating degree days increase, the number of residential structure fires involving flammable liquid and water heaters decreases. No other variables were found to have significant correlations in this fire group. It was assumed that no significant correlations were found due to the low number of data points available in this study.

The literature review predicted there should be correlations between the variables *parent status* and *income* and the number of fires, however, that correlation was not found. This group analysis tested these variables 12 times and found three significant correlations. Considering a Bonferroni Test (George & Mallery, 2001) to adjust for experiment-wise error the p-value (0.05) was divided by the number of tests performed (12) providing a more rigorous test. In this case the threshold for significance is lowered to 0.004 (0.05/12=0.004). Using this more rigorous p-value, none of the tests of this group exhibited a significant correlation. The Bonferroni Test is used when there are 20 or more tests of the same variables used in that analysis to ensure significance is determined correctly. In this case there were only 12 tests in this fire group using the same variables and therefore the Bonferroni Test is not going to be used here to determine the p value of significance.

Table 4.8. Variable matrix and correlation coefficient results for water heater fire group

Tests	education	parent	income	climate
test 25	variable	variable	variable	control
correlation	-0.2207	0.2015	-0.2753	
significance	0.233	0.277	0.134	
test 26	variable	variable	control	variable
correlation	**-0.3647**	0.3271		**-0.4147**
significance	**0.044**	0.073		**0.020**
test 27	variable	control	variable	variable
correlation	-0.3191		-0.3506	**-0.3946**
significance	0.080		0.053	**0.028**
test 28	control	variable	variable	variable
correlation		0.0735	-0.2388	-0.2702
significance		0.695	0.196	0.142
test 29	variable	control	control	control
correlation	-0.0471			
significance	0.808			
test 30	control	variable	control	control
correlation		0.1426		
significance		0.461		
test 31	control	control	variable	control
correlation			-0.2542	
significance			0.183	
test 32	control	control	control	variable
correlation				-0.2727
significance				0.152
test 33	control	control	variable	variable
correlation			-0.2577	-0.2760
significance			0.169	0.140
test 34	variable	variable	control	control
correlation	-0.1607	0.2086		
significance	0.396	0.269		
test 35	variable	control	control	variable
correlation	0.2097			-0.3363
significance	0.266			0.069
test 36	control	variable	variable	control
correlation		0.0938	-0.23157	
significance		0.266	0.218	

Note: Bolded values depict a significant correlation with *water heater fire rate* at $p \leq .05$ using a two-tailed test.

Example: test 26 – *education, parent status, income* and *climate* were all included in the partial correlation. *Income* was the control variable. The effect of *income* was fixed and the resulting correlation coefficients of the other variables reflect their effect only. Comparing test 25 and test 26 the coefficients of *education* and *parent status* grew stronger when *income* was fixed, meaning *income* does not have a strong association here.

Gas Water Heater Fire Group

In an effort to improve the normality of the *gas water heater fire group* variables, several outlier states were excluded. Seven states and the District of Columbia were excluded from Table 4.2 for use in the *gas water heater fire group* calculations of this study: Alabama, District of Columbia, Florida, Georgia, Massachusetts, North Hampshire, Nevada, and Oklahoma. These states were excluded because they either had no representation or contained data values that were deemed outliers. The reason for the values being outliers is unknown, but reasons might include coding errors which might include typing errors, transfer errors, misinterpretation of the code. The normality of the fire variables was improved and is described in the histograms depicted later in this study.

Table 4.9 lists the *water heater fire group* data for each of the states: *fire rate*, *education*, *parental status*, *income*, and *climate* involved in this correlation. Figure 4.8 depicts the histogram of *gas water heater fire rate* with no additional outliers removed from the data set used in the *gas water heater fire group*.

Table 4.10 depicts the matrix of variables used in the *gas water heater fire group* partial correlations. The calculations involved controlling variable or variables in each calculation. Table 4.10 indicates which variables were used as controls in the various tabulations. The dependent variable *gas water heater fire rate* and the four independent variables, *education*, *parent status*, *income*, and *climate*, were used in each calculation.

As depicted in Table 4.10, the bolded cells indicate those variables which appear to correlate significantly at $p \leq .05$. In one of the 12 tests, the variable *climate* negatively correlated to the variable *gas water heater fire rate*. This was interpreted as meaning as the state's average number of heating-degree days increase, the number of residential structure fires involving flammable liquid and gas water heaters decreases. No other variables were found to have significant correlations in this exam. It was assumed that no significant correlations were found due to the low number of data points available in this study. The literature review predicted there should be correlations between the variables *education*, *parent status* and *income* and the number of fires, however, that correlation was not found. This group analysis tested these variables 12 times and found 1 significant correlation. Considering a Bonferroni Test (George & Mallery, 2001) to adjust for experiment-wise error the p-value (0.05) was divided by the number of tests performed (12) providing a rigorous test. In this case the threshold for significance is lowered to 0.004 (0.05/12=0.004). Using this more rigorous p-value, none of the tests of this group exhibited a significant correlation. The Bonferroni Test is used when there are 20 or more tests of the same variables used in that analysis to ensure significance is determined correctly. In this case there were only 12 tests in this fire group using the same variables and therefore the Bonferroni Test is not going to be used here to determine the p value of significance.

Regression Examination

A general linear regression model (SPSS) was used to examine the normality and collenarity of the fire variables used in each of the four fire groups: ***residential structure fire***, ***flammable liquid fire***, ***water heater fire***, and ***gas water heater fire***. The normality was observed using the residual plots of the fire variables and those are Figures 4.5 – 4.8 for the four fire groups. The shaded and bolded cells in Table 4.11 indicate those correlations in the regression that exhibited significance at p=0.05.

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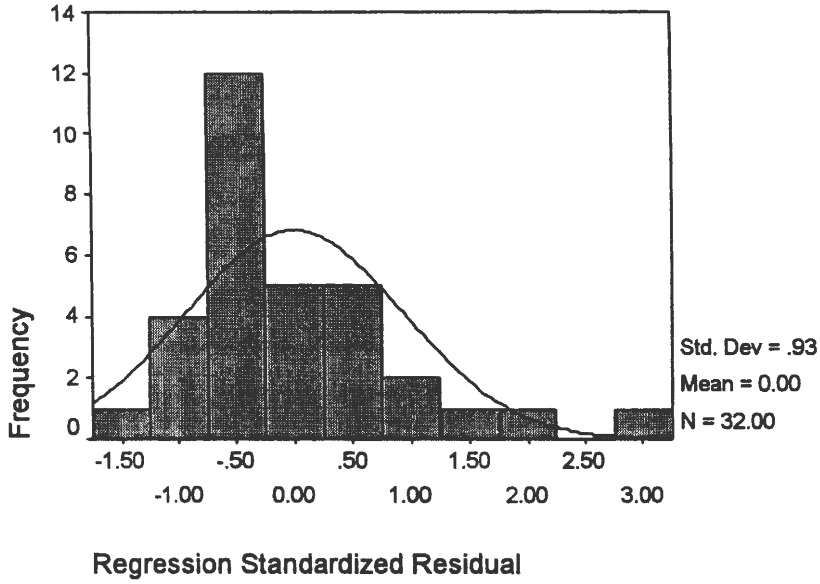

Figure 4.8. Histogram of *gas water heater fire rate* with no outliers removed

This confirms there are significant correlation among the selected socioeconomic and climate variables and the fire data of the four fire groups. Specifically, *education* exhibited significant correlation in the *water heater fire group* and *gas water heater fire group*. The prior literature predicted *education* would be inversely correlated with the fire incident rate and in all four groups that was exhibited here. *Parent status* exhibited significant correlation in the *residential structure fire group*, *water heater fire group* and *gas water heater fire group*. The prior literature also predicted *parent status* would be positively correlated with the fire incident rate and in all four groups exhibited here. *Income status* did not exhibit a significant correlation in any of the fire groups analyzed here. Prior literature predicted income would be inversely correlated with the fire incident rate. *Climate* exhibited a significant correlation in the *water heater fire group* and *gas water heater fire group*.

Table 4.9. Gas water heater fire group with socioeconomic and climate values

State	Gas water heater fire rate	Education	Parent status	Income	Climate
AK	0	90.4	0.077	51993	11699
AR	0.041	81.7	0.073	30527	2927
CT	0	88.2	0.070	51432	5599
HI	0	87.4	0.058	46945	51
IA	0.068	89.7	0.056	42808	6220
ID	0	86.2	0.057	37287	6640
IL	0.044	85.5	0.068	47193	5559
IN	0	84.6	0.068	41010	5307
KS	0.148	88.1	0.060	38220	4428
KY	0.049	78.7	0.069	36113	3985
LA	0.190	80.8	0.097	32006	1322
MD	0.113	85.7	0.080	52881	4254
ME	0	85.1	0.066	46312	5706
MI	0.030	86.2	0.075	46986	6153
MN	0.040	90.8	0.058	49846	7564
MO	0	86.6	0.071	45160	4604
MT	0	89.6	0.059	32169	7394
NE	0.181	90.4	0.059	39332	5741
NJ	0.020	87.3	0.064	51320	4954
NY	0.026	82.5	0.081	41504	5331
OH	0.123	87.0	0.072	42421	5384
OR	0	88.1	0.062	42260	5206
SC	0.089	83.0	0.085	37455	2355
SD	0.139	91.8	0.060	36681	6825
TN	0.073	79.9	0.074	35824	3445
TX	0.308	79.2	0.076	40065	1569
UT	0.044	90.7	0.057	46436	5864
VA	0.030	86.6	0.069	48678	4051
VT	0	90.0	0.061	40589	7449
WA	0	91.8	0.064	44598	5383
WI	0.066	86.7	0.061	46357	6763
WY	0	90.0	0.059	38839	7513

Table 4.10. Variable matrix and correlation coefficient results for gas water heater fire group

Tests	education	Parent status	income	climate
test 37	variable	variable	variable	control
correlation	-0.0980	0.2041	-0.2022	
significance	0.600	0.271	0.275	
test 38	variable	variable	control	variable
correlation	-0.2477	0.3095		**-0.3549**
significance	0.179	0.090		**0.050**
test 39	variable	control	variable	variable
correlation	-0.1615		-0.2718	-0.3248
significance	0.385		0.139	0.075
test 40	control	variable	variable	variable
correlation		0.1574	-0.1931	-0.2726
significance		0.389	0.298	0.138
test 41	variable	control	control	control
correlation	0.0952			
significance	0.623			
test 42	control	variable	control	control
correlation		0.2228		
significance		0.245		
test 43	control	control	variable	control
correlation			-0.2248	
significance			0.241	
test 44	control	control	control	variable
correlation				-0.2829
significance				0.137
test 45	control	control	variable	variable
correlation			-0.2294	-0.2864
significance			0.223	0.125
test 46	variable	variable	control	control
correlation	0.0481	0.2078		
significance	0.801	0.271		
test 47	variable	control	control	variable
correlation	00.0610			-0.2740
significance	0.749			0.143
test 48	control	variable	variable	control
correlation		0.1815	-0.1839	
significance		0.337	0.331	

Note: Bolded values depict a significant correlation with *gas water heater fire rate* at $p \leq .05$ using a two-tailed test.

Example: test 38 – *education, parent status, income* and *climate* were all included in the partial correlation. *Income* was the control variable. The effect of *income* was fixed and the resulting correlation coefficients of the other variables reflect their effect only. Comparing test 37 and test 38 the coefficients of *education* and *parent status* grew stronger when *income* was fixed, meaning *income* does not have a strong association here.

The prior literature also predicted climate might be correlated with the fire incident rate and in two of the four groups that was exhibited here.

The "R" values provide a relative measure of the strength of the model, the larger the value the better the model is working. In these cases the models are functioning reasonably. The tolerance values describe one method of measuring colleniarity. The tolerance value is measured in a range of 0.000 to 1.000. The value closer to 0.000 the more colleniarity there is between the variables in the test. In these cases, the values are not close to 0.000 and therefore a colleniarity problem does not exist in these data.

Empirical Examination

An empirical review of the data set was examined to ensure the correlations and regression analysis appeared to exhibit similar associations from a non-statistical analysis. In this case, Table 4.2 was sorted by the variable *climate* into three climate groups in ascending order, lowest to highest HDD value. The Climate data set (Table 4.12) was then split into three equal size groups, each containing 13 states. Climate group 1 contains the states with the lowest HDD values. Climate group 2 contains the middle group of HDD states. Climate group 3 contains the states with the warmest climate, largest HDD values.

This analysis revealed that the warmest group Climate group 1- those exhibiting the lowest HDD values exhibited greater average climate group fire rates than the next warmer group. Climate group 2 also exhibited an increase in average climate group fire rate compared to Climate group 3, the coldest climate group. This is the same correlation exhibited in the previous analysis.

Table 4.11. General linear regression summary of the fire groups

	Residential structure fires	**Flammable liquid fires**	**Water heater fires**	**Gas water heater fires**
Education Correlation Coefficient (Significance)	-0.210 (0.113)	-0.227 (0.095)	**-0.450 (0.005)**	**-0.327 (0.034)**
Parent status Correlation Coefficient (Significance)	**0.415 (0.007)**	0.123 (0.241)	**0.342 (0.028)**	**0.326 (0.034)**
Income Correlation Coefficient (Significance)	0.001 (0.499)	-0.021 (0.453)	-0.364 (0.200)	-0.290 (0.053)
Climate Correlation Coefficient (Significance)	-0.277 (0.054)	-0.206 (0.118)	**-0.472 (0.003)**	**-0.407 (0.010)**
R value	0.467	0.251	0.561	0.491
R squared value	0.218	0.063	0.315	0.241
Education tolerance	0.373	0.373	0.361	0.361
Parent tolerance	0.586	0.586	0.557	0.557
Income tolerance	0.853	0.853	0.832	0.832
Climate tolerance	0.570	0.570	0.593	0.593

Note: Bolded values depict a significant correlation with $p \leq .05$.

Education exhibited the inverse of the average climate group fire rates. The average *Education* in a climate group increased as the average of all four fire rates in that climate group decreased. This is the same correlation exhibited in the previous analysis. The average climate group percentage of state population having a high school education increased as the climate groups got colder.

The average climate group percentage of a state's households where the head of the household was a female with children, decreases as the climate groups get colder. As the climate groups get colder there are fewer households where the head of the house is a female with children.

Table 4.12. Fire rate, socioeconomic and climate data in relative climate region

	State	Residential structure fire rate	Flammable liquid fire rate	Water heater fire rate	Gas water heater fire rate
Climate Group 1	HI	117.577	0.908	0.000	0.000
	FL	380.263	3.989	1.330	1.330
	LA	87.771	0.859	0.239	0.191
	TX	119.234	2.226	0.377	0.308
	GA	202.620	2.228	0.364	0.273
	SC	81.906	0.493	0.090	0.090
	AR	89.675	0.744	0.165	0.041
	OK	503.325	7.912	0.942	0.565
	TN	133.851	1.244	0.073	0.073
	NV	30.379	9.538	0.000	0.000
	KY	77.045	0.544	0.124	0.049
	VA	74.070	0.438	0.045	0.030
	DC	195.084	3.147	0.349	0.000
	Climate group average	160.985	2.636	0.315	0.227
Climate Group 2	MD	93.647	0.661	0.113	0.113
	KS	109.209	2.157	0.186	0.149
	MO	6.764	0.520	0.000	0.000
	NJ	117.564	0.589	0.061	0.020
	OR	70.118	0.906	0.000	0.000
	IN	9.522	0.000	0.000	0.000
	NY	36.946	0.000	0.032	0.026
	WA	89.230	0.949	0.000	0.000
	OH	127.877	1.083	0.123	0.123
	IL	88.828	1.193	0.088	0.044
	CT	92.848	0.587	0.000	0.000
	MA	604.978	2.432	0.078	0.078
	NE	70.567	1.088	0.181	0.181
	Climate group average	116.777	0.936	0.066	0.057
Climate Group 3	UT	49.392	0.716	0.045	0.045
	MI	45.983	0.423	0.030	0.030
	IA	69.268	0.547	0.103	0.068
	ID	71.029	0.413	0.000	0.000
	WI	103.536	0.863	0.066	0.066
	SD	62.628	1.255	0.139	0.139
	NH	0.000	0.000	0.000	0.000
	ME	24.388	0.000	0.000	0.000
	MT	24.631	0.000	0.000	0.000
	VT	113.408	1.070	0.000	0.000
	WY	58.528	0.405	0.000	0.000
	MN	64.885	0.589	0.061	0.041
	AK	111.316	0.838	0.000	0.000
	Climate group average	61.461	0.548	0.034	0.030

Table 4.12. (Continued).

	State	Education (percent)	Parent status (percent)	Income (dollars)	Climate (HDD)
Climate Group 1	HI	87.4	0.058	46945	51
	FL	84.0	0.069	37540	506
	LA	80.8	0.098	32006	1322
	TX	79.2	0.076	40065	1569
	GA	82.6	0.086	41822	2329
	SC	83.0	0.085	37455	2355
	AR	81.7	0.074	30527	2927
	OK	86.1	0.070	33235	3157
	TN	79.9	0.074	35824	3445
	NV	82.8	0.067	43918	3983
	KY	78.7	0.070	36113	3985
	VA	86.6	0.069	48678	4051
	DC	83.2	0.099	39363	4254
	Climate group average	82.7	0.077	38730	2610
Climate Group 2	MD	85.7	0.080	52881	4254
	KS	88.1	0.060	38220	4428
	MO	86.6	0.071	45160	4604
	NJ	87.3	0.064	51320	4954
	OR	88.1	0.062	42260	5206
	IN	84.6	0.069	41010	5307
	NY	82.5	0.081	41504	5331
	WA	91.8	0.065	44598	5383
	OH	87.0	0.073	42421	5384
	IL	85.5	0.069	47193	5559
	CT	88.2	0.070	51432	5599
	MA	89.3	0.062	40918	5706
	NE	90.4	0.060	39332	5741
	Climate group average	87.3	0.068	44481	5189
Climate Group 3	UT	90.7	0.058	46436	5864
	MI	86.2	0.075	46986	6153
	IA	89.7	0.056	42808	6220
	ID	86.2	0.058	37287	6640
	WI	86.7	0.062	46357	6763
	SD	91.8	0.061	36681	6825
	NH	88.1	0.057	48323	6833
	ME	85.1	0.067	46312	7390
	MT	89.6	0.059	32169	7394
	VT	90.0	0.061	40589	7449
	WY	90.0	0.060	38839	7513
	MN	90.8	0.059	49846	7564
	AK	90.4	0.078	51993	11566
	Climate group average	88.8	0.062	43433	7244

Income exhibited a mix of results. Climate group 1, the warmest climate group exhibited a lower average climate group state income then Climate group 2, the middle climate group. However, the coldest climate group, Climate group 3, exhibited an average climate group income less then Climate group 2, the middle climate group, but greater than Climate group 1, the warmest climate group.

CHAPTER 5. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

In summary, this study examined the possible correlation between the four fire groups and four variables: *education*, *parental status*, *income* and *climate*. This study answered the four posed research questions:

1. To what extent is there a correlation between the incidence of residential structure fires with socioeconomic and climate factors? The household parental status female head-of-household with children (*parent status*) significantly correlated with the number of residential structure fires in a state at the state level (*residential structure fire rate*).
2. To what extent is there a correlation between the incidence of residential structure flammable liquid fires with socioeconomic and climate factors? The household parental status female, head-of-household with children (*parent status*) significantly correlated with the number of residential structure fires involving flammable liquid fires in a state at the state level (*flammable liquid fire rate*).
3. To what extent is there a correlation between the incidence of residential structure flammable liquid fires involving water heaters with socioeconomic and climate factors? The state's average education attainment (*education*) significantly correlated with the number of residential structure fires in a state involving flammable liquids and water heaters at the state level (*water heater fire rate*). Also, the number of HDD in the state (*climate*) had a significant correlation with the number of residential structure fires in a state involving flammable liquids and water heaters at the state level (*water heater fire rate).*

4. To what extent is there a correlation between the incidence of residential structure flammable liquid fires involving gas-fired water heaters with socioeconomic and climate factors? The average number of HDD in the state (*climate*) had a significant correlation with the number of residential structure fires in a state involving flammable liquids where the ignition source was gas water heaters at the state level (*gas water heater fire rate*).

Conclusions

Table 5.1 presents a summary of the variable matrix and the results. The findings are similar to the findings of the TriData Corporation (1997) study, *Socioeconomic Factors and the Incidence of Fire* and that of Gunther (1981) wherein the socioeconomic indicators, parental presence, single parent homes accounted for a variation in fire rates in structures. *Residential structure fire group* revealed there was a correlation of the percentage of households with female head-of-household with children with the rate of fires in a state.

Table 5.1. Summary of variable matrix and results

Fire group & examination	Education	Parent status	Income	Climate
Residential structure fire rate				
Partial correlation examination		X		
Regression examination		X		
Flammable liquid fire rate				
Partial correlation examination		X		
Regression examination				
Water heater fire rate				
Partial correlation examination	X			X
Regression examination	X	X		X
Gas water heater fire rate				
Partial correlation examination				X
Regression examination	X	X		X

Key: X = significant correlation at $p \leq 0.05$

Fifty percent of the 12 partial correlation tests in this group exhibited a correlation with the fire rate. Considering the regression analysis (Table 4.11), *parent status* would be considered a predictor variable in three of the four fire groups' tests, *residential structure fire group*, *water heater fire group*, and *gas water heater fire group*. This study supports the prior studies regarding single parent female head-of-household parental status as being associated with the higher rate of fires.

TriData Corporation (1998) concluded a colder climate was a factor in predicting higher fire incidence in cities because flame-fired home heating appliances are in greater use during the colder months. The current study found the average HDD value for the state *climate* was inversely correlated to the *water heater fire rate* and *gas water heater fire rate* when examined at the state level (Table 4.8 and 4.11). This indicates that fire incidence increases as the HDD for a state decreases. This may reflect on the home construction method most used in warmer climates. Slab-on-grade construction is widely used in warmer regions. This is a result of domestic water supply piping not needing to be protected from the effects of colder weather. Thus, the domestic water supply piping is not buried as deep in the ground and the need of basements to house heating appliances is reduced or not required. Slab-on-grade construction is also used where there are high water tables or rock formations which do not allow easy digging for a basement. Local construction design determines the location where utilities and appliances are located in the home. Each local area can have a preferred location for the installation of the home's appliances. This preferred appliance location may also be a location where flammable liquids might also be stored or used improperly. Therefore, the location where heating appliances are located in the home may have a direct effect of the incidence of fire.

Based on their fire studies, Karter and Donner (1978) recommended that fire departments improve inspections and education in high-risk areas (locations where the fire rate is higher) to decrease fire incidence. Fahy and Norton (1989) revealed that, at the state level, the southern states had more poverty than the northern states. These states were: Alabama, Arizona, Arkansas, Florida, Georgia, Louisiana, Mississippi, New Mexico, North Carolina, Oklahoma, South Carolina, Tennessee, and Texas. This is 62% of the states listed in the warmest climate group, Climate group 1 (Table 4.12). Based on the recommendation by Karter and Donner (1978), and Fahy and Norton (1989), to improve fire inspections and education for high-risk areas, and the fact that Southern states have lower HDD values, it is recommended that education and inspections of the general and flammable liquid fire hazards should be improved in these states. *Education* was not found to exhibit a significant partial correlation in the *residential structure fire group, flammable liquid fire group* or *gas water heater fire group*. Education did exhibit a significant partial correlation in the *water heater fire group*. Considering the regression examination *education* was a predictor in both of the *water heater fire group* and gas *water heater fire group*.

Analysis of the fire group *water heater fire group* found the state's average education attainment (*education*) and average HDD value, (*climate*), significantly correlated with the number of residential structure fires in a state involving flammable liquids and water heaters at the state level (*water heater fire rate*).

The results of the analysis of the *water heater fire group* and *gas water heater fire group* agreed with the studies of TriData Corporation (1997), Gunther (1981), Duncanson et al. (2002), Karter and Donner (1978), and Fahy and Norton (1989) in revealing *education* as a correlating factor in the incidence of structure fires. However, the current partial correlation study revealed *education* to be correlated in only one fire group, *water heater fire group*, but *education* was not found to correlate with general structure fires (*residential structure fire group*). The current study did not investigate why *education* correlated with only one fire group. This could be a topic for future study. The regression examination of this study did predict *education* as a predictor in *water heater fire group* and *gas water heater fire group* (Table 4.11). In addition, the empirical examination revealed there was lower education attainment in the warmer *climate* group where there was a higher rate of fire incidents.

For the fourth group of variables, *gas water heater fire group* found one significant correlation (partial correlation analysis) between the percentage of a states population that had received a high school education, *education,* the average number of HDD in the state, *climate*, the household parental status female, head-of-household with children, *parent status*, and *income,* the state's average household income. A significant correlation was revealed between *climate* and the number of residential structure fires in a state involving flammable liquids and gas-fired water heaters at the state level (*gas water heater fire rate*). Considering the regression examination of this fire group, *education*, *parent status* and *climate* were considered predictors. *Education* exhibited a negative correlation with the *gas water heater fire rate* in this group (Table 4.11) which was predicted in the prior studies. *Parent status* exhibited positive correlation with the *gas water heater fire rate* in this group as was predicted in prior studies. *Climate* exhibited a negative correlation with the *gas water heater fire rate* in this group (Table 4.11). The opposite was predicted in prior studies.

Recommendations

This study was limited to the data available at the state level. Past research examined the incidence of residential structure fires at the city level or census tract level whereas the current study examined data at the state level. It was concluded by this researcher that census tract level is a more revealing method of conducting research with fire data because it provides a considerable greater number of data values, and it matches the socio-economic variables more closely with the fire locations. The following is recommended for future research based on the outcomes of this study:

1. Conduct a nationwide study at the census tract level. This will provide more data values and is more likely to match the actual socioeconomic values to those fire incident locations. Similar studies to this one done at the national level, will likely provide a better view of the effect of the socioeconomic and climate variables on the associated fire incident rates.
2. Conduct a nationwide study of the individual flammable liquid fires using the actual socioeconomic values for that fire incident location. This would provide detailed data on this type of fire which would allow direct statistical analysis of the type of fire.
3. Use logistical regression as the statistical method, using "fire" and "no fire" as the dichotomous variables. When looking at the fire incidents at the census level, some method of statistical methodology must be determined. This study examined the fire data at the state level which allowed the state's fire rate to be the dependent variable. Moving the study to the census tract level removes the dependent variable and some other dependent variable must therefore be found. Using logistical regression, the dichotomous value of, "fire" and "no fire" can be used as the dependent variable.
4. Further study into the generally accepted use of typical household appliances and the rate of fire incidence involving that home appliance should be done. This type of study might determine if there is a need to improve the instructions, education or

design of typical household appliances that might affect the rate of fire incidents involving home appliances.

5. Further study in the incidence of flammable liquid fires involving typical household appliances might include an examination of the quantity of the typical household appliances located in a given geographic (climate) location compared to the rate of fire incidents and socioeconomic factors in that location. This examination might provide basis of determining if the design of a typical household appliance or the typical installation location had an effect on the rate of fire incidents in that climate.

The following are recommendations for the fire prevention community based on the out comes found in this study.

1. Improve fire inspections and fire hazard education programs in Southern states. This study determined there was a high rate of fire incidents in the Southern states. This confirmed past studies, Tables 4.8 and 4.11. Improving fire education in the warmer climate areas might have a positive effect on the reduction of the rate of fire incidents.
2. Require NFIRS information to include census tract numbers that match the incident address. This would provide a direct relationship to Census information. Having the NFIRS fire data coupled with the census tract number would provide a significantly easier and improved fire data source to examine the incidence of fires. Currently the NFIRS fire data provides a location for the census tract level information in the reports, but the reporting fire departments do not typically provide that information

A responsible effort to reduce the rate of fire incidents will have a significant impact on the people involved in those fires. This effort might include improved or focused education programs regarding the causes of fires in the home, improved or more focused education and inspection of the installation of appliances in the home, or improved or more focused education programs concerning the safe handling of flammable liquids in the home. The reduction of the human suffering and property loss caused by fire is a noble and worthwhile effort.

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