SOCIOECONOMIC FACTORS AS DETERMINANTS OF NOISE ACCEPTANCE

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Among the many factors that influence residents living adjacent to a major transportation facility is noise. Since the ultimate criteria of public acceptance are based on annoyance levels rather than absolute noise levels, an investigation was undertaken concerning the relationship between annoyance and socioeconomic characteristics, such as social status, length of residence, and age, in primarily single-residence neighborhoods. Criteria for selection of the study areas were variation of neighborhood age, homogeneity, property values, proximity to a noise-generating transportation system, and freedom from other major noise generators, such as airport flight patterns. Although traffic volumes ranged from 84,000 to 52,000 average daily traffic, the noise levels were fairly similar in the study areas. The current assessed value of each improved residential property abutting the highway was obtained from the property tax assessors of Jefferson and Denver counties in Colorado. A total of 110 residences were sampled from a total population of 170 to determine the quantity and characteristics of highway noise annoyance. The results of this investigation show that socioeconomic variables explain only 5.6 percent of the variance in annoyance and that further investigation is not warranted.

•AMONG the many factors that influence residents living adjacent to a major transportation facility is noise. The effects of noise include interference with leisure, sleep, or conversation; decreased efficiency in both physical and mental tasks; fatigue; and potential or actual hearing loss.

Today, transportation planners are considering measures for noise abatement in planned projects as well as in existing problem corridors. The current popular evaluation technique involves field measurement of existing ambient noise levels and extrapolation to present or future design levels based on design traffic characteristics. Federal guidelines establish threshold levels above which some corrective measures should be taken.

Since the ultimate criteria of public acceptance are based on annoyance levels rather than on absolute noise levels, an important tool that could be used by transportation planners would be a guideline for determining the sensitivity of neighborhoods to noise generated by transportation systems.

This study proposes to evaluate the annoyance levels in single-residence neighborhoods displaying various socioeconomic characteristics where a similar noise environment exists and to determine the correlation between annoyance levels and certain socioeconomic characteristics.

PREVIOUS RESEARCH

Before the project goals were defined, an extensive review was undertaken of all available research material at the University of Colorado libraries, Denver Public Library, Colorado Department of Highways, and the noise office of the city of Lakewood. Because of the extensive research related to quantifying noise and attenuation techniques, annoyance due to transportation noise was investigated.

Hawel (1) discussed parameters for annoyance. The primary parameters discussed were situation, personality, activity, quality of sound, and noise level. Situation was examined relative to work, recreation, and sleeping; personality to humor; and activity to relaxing, arithmetic problems, and composition. Types of noise investigated ranged from traffic and construction noise to voices and music.

Kryter (2) discussed psychological techniques for reduction of annoyance levels and defined various techniques for evaluating certain components of noise to determine annoyance.

A study (3) of noise problems prepared before the Bay Area Rapid Transit System was constructed recommended that the cultural, economic, and leadership character of wayside communities be surveyed to determine the likelihood of complaints and possible legal action so that particular attention could be paid to noise control in sensitive areas.

As a result of these and other readings, it was decided that an investigation into the relationship between socioeconomic characteristics and levels of highway noise annoyance was warranted for possible use as a planning tool to be used by transportation planners and others concerned with noise abatement.

The following definitions are used in our paper:

dBA = single number rating read directly from the A scale of a sound-level meter that has electronic filters that approximate the human ear's response to different frequencies; the rating has a high correlation with nearly steady-state wide-band, non-information-carrying noise, such as traffic noise (4);

L_{10} = noise level (dBA) that is exceeded 10 percent of the time;

L_{50} = noise level (dBA) that is exceeded 50 percent of the time; and

ambient noise = all-encompassing noise that is a composite of sounds from many sources at varying distance.

STUDY DESIGN

Selecting Study Areas

After the initial objectives had been established, the initial phase of the project was to select study areas. Criteria for selection of the study areas were variation of neighborhood age, homogeneity, property values, proximity to a noise-generating transportation system, and freedom from other major noise generators, such as airport flight patterns.

The primary study area was US-6 between Federal and Kipling Boulevards, a 4.5-mile (7.2-km) section of divided six-lane highway with average daily traffic (ADT) varying between 82,000 and 52,000 vehicles per day. Values of homes abutting US-6 range from less than \$10,000 to more than \$60,000. Some of the homes lie in relatively new subdivisions, less than 10 years old, and others are located on lots in excess of 1 acre (0.4 hm^2) with horses and other similar rural amenities. Some of the older subdivisions have been established for 50 years.

A secondary study area, located along I-25, contains a new (less than 10 years) and homogeneous neighborhood of upper middle class homes. These homes abut the four-lane divided highway, which is currently planned to be expanded to six lanes. The ADT along this section of highway is 84,000 vehicles per day. Most of these homes have low fences, are set back further from the highway than most homes in the primary study area, and have a mean value of \$50,000.

Determining Noise Levels

The process used to determine noise levels for the study areas began with field measurements of approximately sixty readings (dBA) at 5-sec intervals and simultaneous automobile and truck counts. The number of occurrences at each dBA level and of the measurement intervals, the distance from the center of the near lane, the percentage of the highway grade, the height above the highway at which the measurements were taken, the automobile and truck counts, the posted speed, and the design (current peak-hour) automobile and truck volumes were compiled. For the purpose of the study, 1972 Colorado Department of Highways traffic data were updated to the current year.

The Colorado Department of Highways computer program NODATA was used to compute L_{50} and L_{10} noise levels at the time of measurement and to extrapolate noise levels to design operation. In addition, the accuracy of each set of readings was computed. This method was used to standardize all noise data to be compatible with any other highway data. Although traffic volumes ranged from 84,000 to 52,000 ADT, the noise levels were fairly similar in the study areas.

Noise levels at 50 ft (15.2 m) from the near lane were determined for each of five sections in the primary study area and the supplementary study area where traffic volumes were the same. Noise levels (L_{10}, dBA) were then established for each residence by scaling aerial photos for the distance from the centerline to the near edge of each residence and by computing attenuation due to distance by $-20 \times \log$ (distance/50) (5). Although characteristics of terrain and vegetation varied, we thought that these factors would not greatly affect the final results of the study.

Determining Annoyance

We wanted to interview as many residents as possible whose houses abutted the highway. Multiunit dwellings were avoided since it was thought that apartment residents would be more compromising in their noise acceptance than those living in single residences. However, seven duplex residences were surveyed because they were part of largely single-residence neighborhoods. A total of 110 residences were sampled from a total population of 170.

In series 1, the following questions were asked of each person surveyed:

1. Given the categories of very high, high, disturbing, or no concern, how would you rate your concern about air pollution as it affects you?
2. Given the same categories, how would you rate your concern about water pollution as it affects you?
3. Given the same categories, how would you rate your concern about noise levels, as they affect you?

The ratings for each response are given in Table 1. The purpose of the indirect lead-in was to avoid immediate bias against highway noise, since it has been shown that early direct questioning on noise tends to bias the level of annoyance (6).

The question in series 2 was, What source of noise bothers you most: people, machinery, aircraft, or surface transportation? The ratings of responses are given in Table 1. The particular sources for the responses were determined as follows:

1. People—shouting, radio, T.V., children, dogs, or playgrounds;
2. Machinery—lawn mowers, chain saws, or construction equipment; and
3. Surface transportation—cars, trucks, motorcycles, buses, or trains.

Trains was never given as a response.

Series 3 determined whether the noise bothered the respondent at home by the following questions:

1. Where does noise bother you most: home, work, commuting, or recreation?
2. Does noise bother you more indoors or outdoors?
3. Does noise bother you more while you are sleeping or working?

Questions 2 and 3 were asked when the response to question 1 was home. The values assigned to each response are given in Table 1. The weighting of the responses from question 1 in series 3 was designed to place more emphasis on the responses of those whose source of annoyance was the highway and to give minor consideration to those whose annoyances were transportation oriented. The values attached to question 2 were used to give additional consideration to those whose noise problems stemmed from areas where levels were lower because of the significant attenuation inside a dwelling. Similarly, for question 3, sleeping was given more consideration than working because a person is apt to be more sensitive when sleeping.

The questions in series 4 were as follows:

1. When does noise bother you most: summer or winter?
2. Is there a particular time of day when noise bothers you more: morning, afternoon, or evening?

These questions were weighted as given in Table 1. Winter was weighted heavier because traffic volumes are lower and people are less likely to be outside. The time of day variables were given arbitrary assignments.

The questions in series 5 were as follows:

1. Do you think that there is adequate noise control legislation?
2. Would you consider joining an organization whose purpose is to have noise levels reduced?

Question 2 was asked if no was the answer to question 1. Questions in series 5 were designed to verify and strengthen the annoyance level determined from the previous responses. The responses were weighted as given in Table 1.

In series 6, there was a single noise-related question: Do you think that noise has increased over the past 5 years? The weighting of responses is given in Table 1. The purpose of this question was to determine residents' awareness of the noise around them.

The following demographic questions were then asked:

1. How long have you lived in this area?
2. What is your occupation?

The occupation categories (not including the unemployed category) are given in Table 4. The following information was determined at the time of interview by the interviewer:

1. Date;
2. Time;
3. Address;
4. Age of respondent;
5. Weather—rainy, cloudy, sunny;
6. Temperature—cool, mild, hot;
7. Interview situation—indoors or outdoors; and
8. Noise at the time of interview—quiet, moderate, or loud.

Determining Property Values

The current assessed value of each improved residential property abutting the highway was obtained from the property tax assessors of Jefferson and Denver counties in Colorado. A recent study by the Colorado Property Tax Division determined that property was currently being assessed at a rate of 13.9 percent in Jefferson County and 23.1 percent in Denver County. Assessed values were adjusted accordingly. Neighborhood groupings were then made by natural breaks (major streets, changes in land use, or major changes in residential character). Mean property values and standard deviations were computed for each parcel abutting the highway in each neighborhood.

Property values for the entire neighborhood were not considered since property values for residential parcels abutting the highway were shown to be substantially lower where noise is a problem (7).

Figures 1, 2, 3, 4, and 5 show locations where noise measurements were taken ▽ and the corridor along the highway where peak noise levels exceed the current Federal Highway Administration standards (8, 70 dBA, outside residential areas) ≈≈≈≈. Homes interviewed in this survey are shown by ◆. Because the primary study area is being considered for possible noise abatement by the Colorado Department of Highways, FHWA is currently undertaking a similar survey. Homes interviewed in the FHWA survey are shown by ◇. The scale on these figures is approximately 1 in. (2.5 cm) equals 700 ft (213 m).

RESULTS AND STATISTICAL ANALYSIS

Variables Analyzed

The following variables were used in this study:

CONAIR = response to concern about air pollution,
CONWATER = response to concern about water pollution,
CONNOISE = response to concern about noise levels,
SOURCE1 = basic noise source (e.g., surface transportation),
SOURCE2 = specific noise source (e.g., trucks),
WHERE1 = where, specifically, noise is a problem (e.g., home),
WHERE2 = where, generally, noise is a problem (indoors or outdoors),
WHERE3 = where activity is when noise problem is greatest,
WHEN1 = time of year when noise problem is greatest,
WHEN2 = time of day when noise problem is greatest,
LEGCOCN = response to question regarding adequate noise control legislation,
LGCOCN2 = response to question regarding joining a noise control organization,
AWARE = awareness of noise increase,
LENGTH = length of residence in years (or fraction thereof),
AGE = age of respondent,
OCCUP = occupation,
TIME = time of day of interview,
ENV1 = temperature,
ENV2 = weather,
ENV3 = indoor or outdoor interview,
ENV4 = noise at interview,
MVAL = market value of property,
RESTYPE = single or multiple unit,
MEANVAL = mean market value of neighborhood properties abutting highway,
STDEV = standard deviation of neighborhood properties,
IMPRATIO = ratio of assessed value of improvements to assessed value of land,
RESFCTR1 = MVAL - MEANVAL,
RESFCTR2 = MVAL - MEANVAL/STDEV,
ANNOY = composite annoyance,
DISTFCTR = distance from the center of downtown Denver to each house,
DIST = distance from the center of highway to near edge of dwelling,
NOISELV = noise level computed to the near edge of house by means of DIST,
L_{10} = L_{10} noise levels at 50 ft (15.2 m) from near lane, and
L_{50} = L_{50} noise levels at 50 ft (15.2 m) from near lane.

IMPRATIO, RESFCTR1, and RESFCTR2 were used to evaluate the relationship between individual property and neighborhood property values.

Table 1. Responses to questions and ratings.

Series	Question	Response	Rating
1	1, 2, 3	No concern	0
		Disturbing	1
		High	2
		Very high	3
2	1	People	1
		Machinery	1
		Surface transportation	5
		None	0[a]
		All	2[b], 4[c]
3	1	None	0
		Recreation	1
		Work	1
		Commuting	2
		All	3
		Home	5
	2	Outdoors	2
		All	3
		Indoors	4
	3	Working	2
		All	3
		Sleeping	4
4	1	None	0
		Summer	1
		All	2
		Winter	3
	2	None	0
		Morning	1
		Afternoon	2
		Evening	3
		All	4
		Multiple	5
5	1	Yes	1
		Uncertain	2
		No	3
	2	No	1
		Uncertain	2
		Yes	5
6	1	No	0
		Uncertain	1
		Yes	3

[a]Also for other than transportation-related sources. [b]Single response. [c]Multiple response.

Figure 1. Sixth Avenue, Kipling Street to Carr Street.

Figure 2. Sixth Avenue, Carr Street to Otis Street.

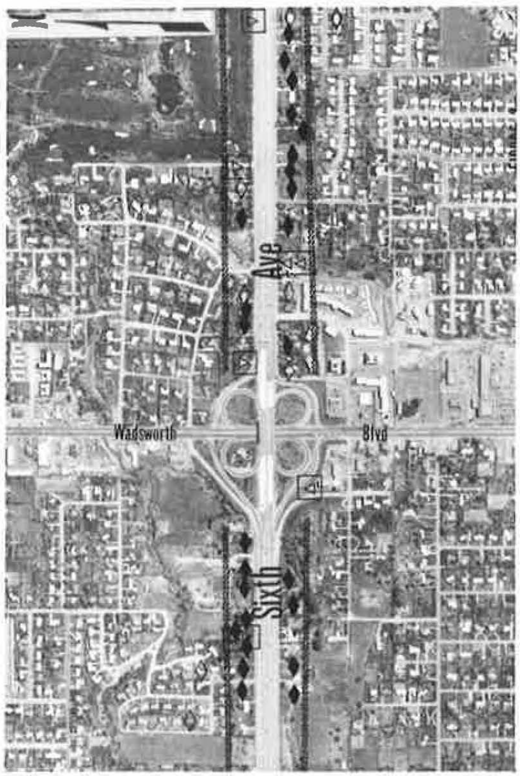

Figure 3. Sixth Avenue, Otis Street to Xavier Street.

Figure 4. Sixth Avenue, Xavier Street to Knox Court.

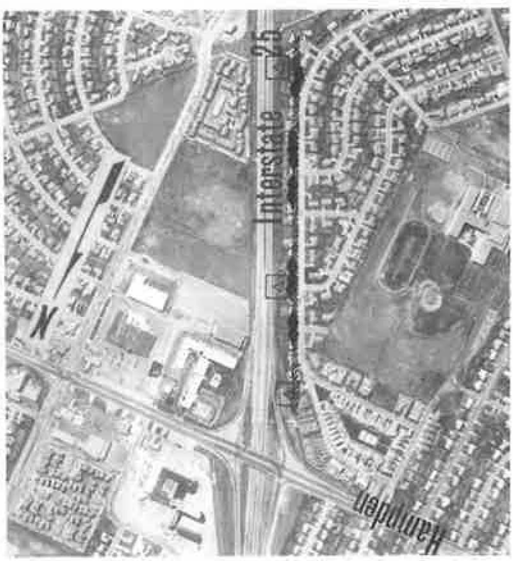

Figure 5. I-25, Hampden Boulevard south.

Table 2. Correlation values above 0.50.

Correlation	Value	Correlation	Value
NOISELV with DIST	0.77[a]	MEANVAL with DISTFCTR	0.80[c]
MVAL with MEANVAL	0.82[b]	MVAL with DISTFCTR	0.70[c]
MVAL with RESFCTR1	0.54[b]	LENGTH with AGE	0.52[d]
MVAL with RESFCTR2	0.52[b]		

[a]Expected since noise level is computed nonlinearly from distance.

[b]Not significant since all these variables are constructed from MVAL.

[c]Peculiar, although probably typical relationship between property values and distance from CBD of a city the size of Denver.

[d]Not surprising since length of residence depends on person's age.

Composite Variable of Annoyance

Since there are several questions relating to annoyance, a single variable representing annoyance was to be developed. The following variables were thought to be most significant in their association with annoyance: CONNOISE, WHERE1, SOURCE1, LEGCOCN, and LGCOCN2. CONNOISE, representing the general noise concern, was used as a key variable, and WHERE1 and SOURCE1 were used as multipliers to define and weight the annoyance as highway-related annoyance at the respondent's home. The questions regarding adequate legislation and possible joining of a noise control organization (LEGCOCN and LGCOCN2) were handled separately and added to the previously computed value, as shown below:

$$\text{ANNOY} = \text{CONNOISE} \times (\text{SOURCE1} + \text{WHERE1}) + \text{LEGCOCN} \times \text{LGCOCN2} \quad (1)$$

For example, if a person was very concerned about noise levels (CONNOISE = 3), indicated the highway as the source of the noise (SOURCE1 = 5), was most disturbed at home (WHERE1 = 5), thought there was inadequate noise control legislation, and was even willing to join a noise control group (LEGCOCN = 3; LGCOCN2 = 5), the person would be given a maximum score of 45. On the other hand, if the source of noise is other than the highway or if the noise problem is greater in a location other than the home, the annoyance level would be substantially lower. The possibility of a particularly noisy place of employment was examined by the subprogram CROSSTABS that compared occupation with WHERE1.

Variable Correlation

The first part of the analysis phase was to compute means and standard deviations for each of the variables and a correlation matrix by the statistical package for the social sciences (SPSS) on the University of Colorado's computer. All correlations above 0.50 are given in Table 2. There is an extremely low correlation between ANNOY and the socioeconomic variables (Table 3). The best correlation, although very poor, is CONAIR. Since annoyance is a composite of the variables related to the annoyance questions, they were not included in Table 3.

Sample Distribution

As a check for biased sampling, Table 4 gives frequencies of certain characteristics of the respondents. Age, length of resistance, and market value are well distributed. On the other hand, occupation has only light representation in factory, sales, labor, and self-employed categories, and housewives dominate the occupation frequency (39.1 percent). However, the survey represents 65 percent of the total households abutting the freeway. Table 4 also indicates that most of those surveyed live within a similar proximity of the highway and that 93.6 percent live in single-residence dwellings. Table 5 shows the absolute and relative frequencies for ANNOY; they demonstrate a great deal of variance.

A factor analysis was performed so that a better correlation matrix could be developed. This, however, did not significantly affect the relationship between socioeconomic variables and annoyance variables. Further occupation data were stratified by distance from the highway, and a cross-classification analysis was performed. Again no significant relationship was developed.

Table 3. Correlation coefficients of composite annoyance variable related to other socioeconomic variables.

Variable	Value	Variable	Value
DIST	0.13785	MEANVAL	0.13362
NOISELV	0.09457	ENV1	0.15145
DISTFCTR	0.04312	ENV2	0.02399
MVAL	0.11117	ENV3	-0.14134
RESFCTR1	-0.00171	ENV4	-0.01834
RESFCTR2	0.02016	TIME	-0.09280
IMPRATIO	0.14123	CONAIR	0.44375
AGE	-0.00928	CONWATER	0.02065
LENGTH	-0.03965	AWARE	-0.15345
RESTYPE	0.21328		

Table 4. Frequency distributions of certain characteristics of respondents.

Item	Description	Relative Frequency (percent)
Age, years	<20	7.3
	20 to 29	18.2
	30 to 39	20.9
	40 to 49	24.6
	50 to 65	14.5
	>65	14.5
Occupation	Professional	15.2
	Office	5.5
	Sales	1.8
	Self-employed	3.6
	Laborer	4.5
	Factory	2.7
	Housewife	39.1
	Retired	15.5
	Student	11.8
Type of residence	Duplex	6.4
	Single	93.6
Length of residence, years	<1	12.7
	1 to 5	32.8
	6 to 10	14.5
	11 to 15	13.6
	16 to 20	9.1
	21 to 25	5.5
	>26	11.8
Market value of property, dollars	<10,000	3.6
	10,000 to 19,999	20.0
	20,000 to 29,999	22.8
	30,000 to 39,999	22.7
	40,000 to 49,999	20.0
	50,000 to 59,999	8.2
	>60,000	2.7
Distance from center of highway, ft	<100	20.0
	100 to 200	74.5
	200 to 300	5.5

Note: 1 ft = 0.3 m.

Table 5. Computed frequencies for composite annoyance variable.

Value	Absolute Frequency	Relative Frequency (percent)	Value	Absolute Frequency	Relative Frequency (percent)
1	3	2.7	22	4	3.6
2	7	6.4	23	2	1.8
4	4	3.6	24	4	3.6
5	1	0.9	25	5	4.5
6	1	0.9	27	1	0.9
7	1	0.9	28	1	0.9
9	2	1.8	30	1	0.9
10	4	3.6	31	1	0.9
11	3	2.7	32	4	3.6
12	1	0.9	33	11	10.0
13	2	1.8	34	2	1.8
14	7	6.4	35	3	2.7
15	1	0.9	36	7	6.4
16	2	1.8	45	20	18.2
17	2	1.8	Total	110	100.0
21	3	2.7			

Table 6. Multiple regression summary for composite annoyance as dependent variable.

		F to Enter						Overall F	
Step	Variable Entered	Value	Significance	Multiple R	R^2	R^2 Change	Simple R	Value	Significance
1	RESTYPE	5.15	0.025	0.21	0.05	0.05	0.21	5.15	0.025
2	NOISELV	3.85	0.052	0.28	0.08	0.03	-0.20	4.57	0.012
3	MVAL	0.52	0.473	0.29	0.08	0.00	0.10	3.20	0.026
4	DISTFCTR	0.59	0.444	0.30	0.09	0.01	0.04	2.54	0.044
5	AGE	0.20	0.658	0.30	0.09	0.00	-0.02	2.06	0.077
6	IMPRATIO	0.17	0.680	0.30	0.09	0.00	0.14	1.73	0.122
7	RESFCTR2	0.11	0.743	0.30	0.09	0.00	0.02	1.48	0.181

Multiple Regression Analysis

The final analysis subprogram used was REGRESSION, in which a stepwise multiple regression was performed. The dependent variable used was ANNOY. As given in Table 6, these socioeconomic variables only explain 5.6 percent of the variance of ANNOY.

So that the possibility of poor construction of the annoyance variable ANNOY could be considered, a similar regression analysis was performed by using all of the annoyance variables as independent variables and MVAL as the dependent variable. The results indicate that little of the variance of the variable MVAL can be explained by the annoyance variables. No significant relationship between the socioeconomic characteristics investigated and the annoyance factors was discovered.

CONCLUSIONS AND RECOMMENDATIONS

Unquantifiable Results

Two respondents thought that the construction of I-70, a parallel route to US-6, had removed a great deal of truck traffic. If some truck traffic has been diverted, it has nevertheless continued to increase along US-6. Annoyance levels for these two respondents were lower, and this agreed with the idea that annoyance levels are closely associated with psychological attitudes (9).

Many of the interviews that were conducted in extremely high noise levels resulted in rather low annoyance levels. Before the data analysis phase, a strong relationship between low annoyance levels and length of residence was expected because these people had gradually become accustomed to their noise environment. However, a significant fraction of the long-term residents are actively involved in a citizens' group attempting to have noise levels reduced. Therefore, length of residence can result in a gradual conditioned response to noise; it also can increase annoyance for those who feel that their activities are increasingly being interrupted by noise. Thus, length of residence, like other socioeconomic characteristics, can play either a positive or negative role in the determination of annoyance.

Other Considerations

A final, single direct question regarding the specific annoyance of the highway at home might have been helpful to verify the composite annoyance variable. However, it is not expected that this would have had a significant effect on the results of this study. Since evidence is increasing that noise increases susceptibility to emotional problems and loss of sleep, which results in increased irritability and tension (10), indirect questioning might have been considered for indicators of personal stress to give minor consideration to psychological factors.

As given in Table 5, the socioeconomic characteristics are well distributed. The types of neighborhoods sampled ranged from those with homogeneous track homes to those with long-established homes on large lots. The survey investigated all major types of single-residence neighborhoods, and as such is a valid representative sample. The composite variable ANNOY was also well distributed, and this provided an opportunity for developing a correlation to related factors.

Through a larger sample, a better relationship between annoyance and socioeconomic variables might be developed. However, a major improvement in the 5 percent explanation of variance would still not result in a significant relationship. Because of this, further analysis and investigation does not appear to be warranted.

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