# COMMENTARY

## Statistical Environmental Justice Assessment for a Transportation Corridor

John R. Larson, Jay A. Claussen

**Executive Order 12898 requires federally sponsored transportation projects to evaluate environmental justice criteria. These federal requirements for transportation studies have proven difficult to evaluate because of the wide range of potential scenarios that can disproportionately affect sensitive populations (either low-income or minority groups). Therefore, environmental justice assessments typically have been conducted in geographically broad areas without refined resolution for the populations closest to the transportation route. This study uses geographic information systems technology with statistical methods to provide for a more refined analysis at the census block level. The study centers on a proposed commuter rail project in the Interstate 35 corridor in the eastern Kansas/Kansas City, Missouri, area. The project involves construction of five new commuter rail stations, and the study aims to ascertain whether construction and operation of the rail system would have disproportionate impacts on low-income people. Comparisons of the median incomes in census blocks in the county with the census blocks within a one-mile radius of the five proposed stations are provided as the basis for a quantitative environmental justice assessment. The environmental justice parameter of low-income level was evaluated using analysis of variance. Results of the study indicated that the mean of the median incomes in census blocks around one rail station differed significantly from the mean of median incomes in the census blocks around the other four stations, and from the blocks in the rest of the county. The study is useful for demonstrating the importance of using a quantitative method as a tool for environmental justice assessment.**

**Environmental Practice 6:71–78 (2004)**

Advanced planning and environmental studies for a New Start commuter rail service on existing heavy rail trackage along the Interstate 35 corridor was conducted between Johnson County, Kansas, and downtown Kansas City, Missouri, in order to address growing traffic congestion along the corridor. The proposed commuter rail transit system, using existing tracks, may significantly relieve traffic congestion, improve air quality, and improve the level of transportation service in the metropolitan area. As part of the planning activities, the study included an environmental justice assessment (EJA) of the socioeconomic parameter of low income. The EJA was performed to evaluate potential future impacts of the proposed rail service to sensitive human populations along the corridor.

The importance of evaluating socioeconomic parameters (such as low-income population distributions) in proximity to proposed major construction developments has been a growing issue for determination of impacts for projects subject to National Environmental Policy Act (NEPA) requirements. Environmental practitioners and agency reviewers often rely on mostly qualitative methods, such as mapping low-income areas and providing supporting anecdotal information, when they document study parameters for EJA. Executive Order 12898 (1994) requires that environmental justice criteria such as low income and minority status be evaluated for federally sponsored projects. This study focuses on use of a quantitative method (analysis of variance) to refine qualitative data and thus provide a more objective analysis in the EJA process.

The study area is approximately 21 miles long and 2 miles wide (see Figure 1). The proposed addition of the new rail service along an existing freight rail corridor includes construction of five new commuter rail stations. The five stations would be located at intervals along the rail alignment (shown on Figure 1), beginning south of the

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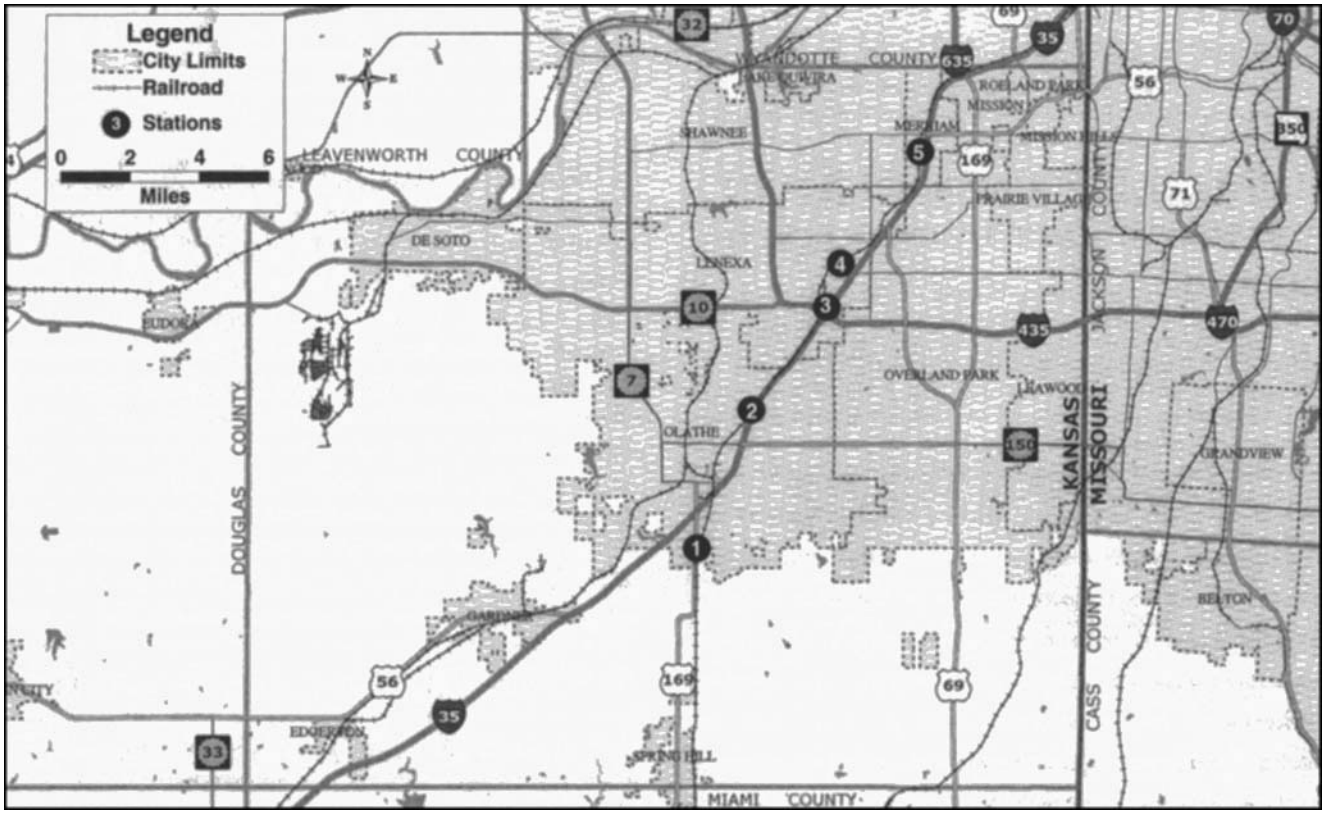


**Figure 1.** Study area for environmental justice assessment, proposed commuter rail project in the Interstate 35 corridor, eastern Kansas/Kansas City, Missouri, area. (Source: US Census Bureau.)

City of Olathe in a mostly rural portion of Johnson County, Kansas (Station 1), and ending at the City of Merriam (Station 5), a metropolitan community adjoining the Kansas City corporate limits.

This study does not include findings of potential impacts by commuter rail associated with historic resources, parklands, wetlands, vibrations, hazardous materials, and other categories for evaluation subject to NEPA for a project of this nature. The objective of this study was to determine whether any sensitive populations, specifically related to low-income levels, would be significantly or disproportionately affected by the construction and operation of the commuter rail project at the proposed station locations or along the rail alignment. The EJA was designed to evaluate human health and environmental conditions in low-income communities, consistent with Executive Order 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" (Executive Order 12898, 1994). Other parameters such as air toxics, noise, or minority status were not evaluated as part of this study. These other parameters could use similar techniques of geographic information systems (GIS) census block mapping combined with statistical methods (such as chi-square analysis of the minority parameter) to provide further objectivity in the EJA process.

This commuter rail transportation project is somewhat distinct, in that issues exist connected with the fact that stations cannot be relocated due to the exisiting infrastructure of the rail line. Therefore, action alternatives (except a no-action alternative) are largely associated with proposed stations *predominantly* along Interstate 35 (paralleling the mainline rail line) and with the total avoidance of any negative impact on low-income populations. In the absence of regulatory guidelines for EJA issues related to Federal Transit Administration funded projects, we developed a quantitative method based on statistical procedures and on GIS-enabled capabilities for characterizing population data. GIS is a computer software tool that enables the user to map a variety of data sets and information with spatial precision. For this study, the initial step involved the identification of low-income populations that

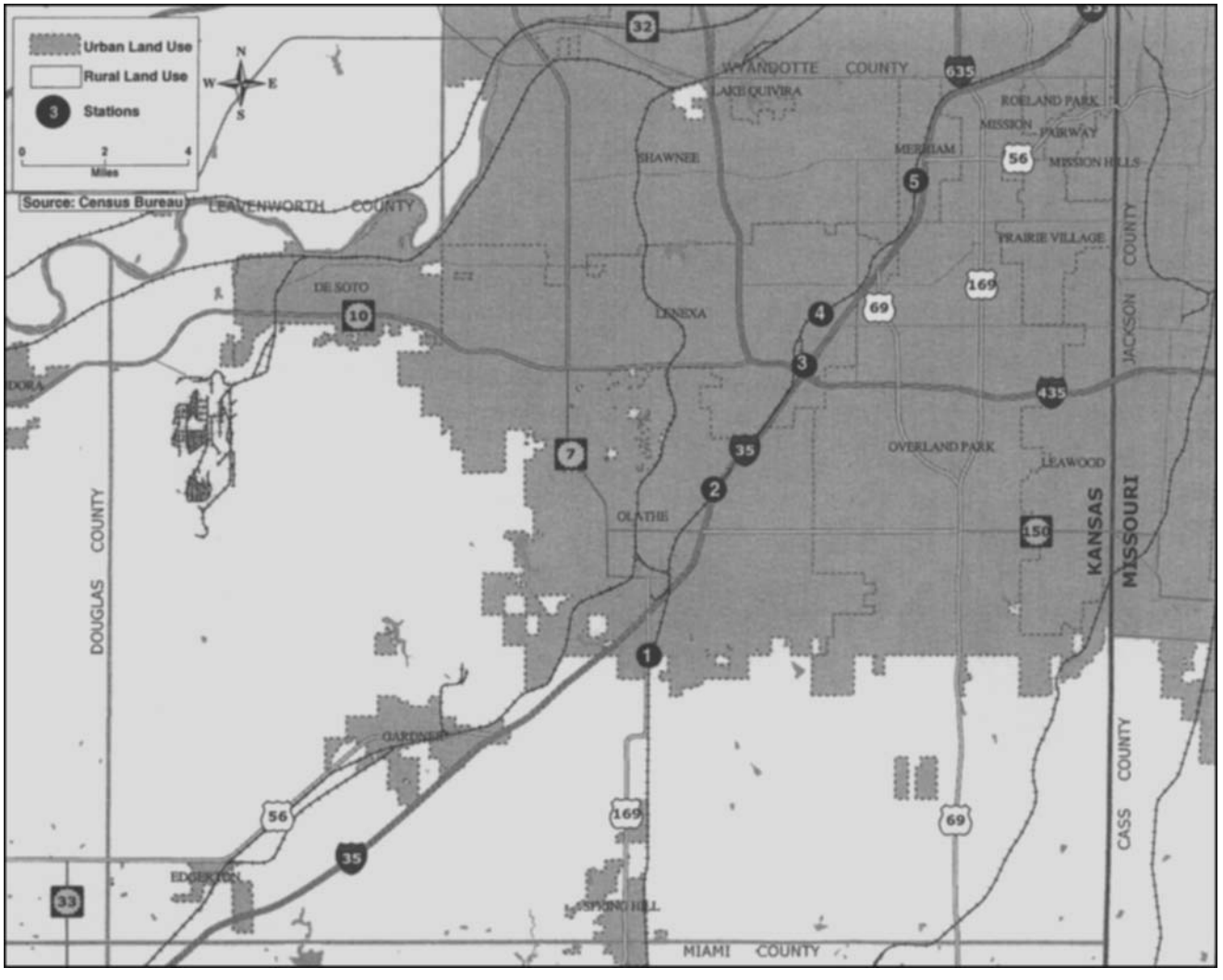


**Figure 2.** Study area land uses, proposed commuter rail project in the Interstate 35 corridor, eastern Kansas/Kansas City, Missouri, area. (Source: US Census Bureau.)

could be directly or indirectly affected by the construction and operations of the proposed project. Because identification of the qualitative sensitive population data alone was not conclusive in determining "disproportionate" impacts, quantitative assessment using statistical methods was also performed to demonstrate whether "disproportionate" impacts could occur as a result of the proposed commuter rail project.

An important aspect of this study was the recognition of dynamic population growth, especially in the southern portions of Johnson County, in formerly rural areas (see Figure 2). Historically, Johnson County has grown from a rural, mostly agricultural region to a county dominated by urban, metropolitan land uses. Thirty years ago, for example, the urban–rural boundary was located near the Interstate 435 corridor north of where it is now located (see Figure 2). As such, only Station 1 has a high proportion of rural residents, and of those residents, most own large properties not used for agricultural purposes.

## Exploratory Data Characterization

The demographic parameter of median income describing the population within the area was identified through available authoritative published sources (US Census Bureau, 2000). Census data parameters from 1990 were retrieved from readily available information published by the US Department of Health and Human Services (2001).



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**Table 1.** Descriptive statistics for income group populations

| Number of blocks | Study area | Total population | Mean of the median incomes of blocks in data set |
|---|---|---|---|
| 4 | Station 1 | 4,004 | 44,932 |
| 6 | Station 2 | 16,830 | 36,886 |
| 8 | Station 3 | 13,644 | 40,275 |
| 11 | Station 4 | 20,403 | 45,719 |
| 15 | Station 5 | 18,501 | 33,379 |
| 206* | County | 355,054 | 49,037 |

* Blocks in the five station study areas were subtracted from the Johnson County total to prevent double counting.

Data from all census blocks in Johnson County, Kansas, formed the empirical evidence for this study. A circle with radius of one mile was drawn around each proposed station. Any census block that fell entirely or partially within the circle around a station was considered "impacted" by the station and thus was in the station's "study area." Census blocks outside the five study areas were the blocks used to characterize the county as a whole. The background Johnson County comparison level included all census blocks in the county with reported income levels, minus the census blocks within each station study area. The subtraction of blocks in study areas from the cumulative county total eliminated the potential for "double-counting" of census blocks. The one-mile radius was selected based on discussions with stakeholders of the most likely potentially impacted populations directly affected by the proposed project.

The sensitive populations of low-income groups were identified by the median household incomes of each census block, and their locations were indicated on the base maps. This information was used to identify potential

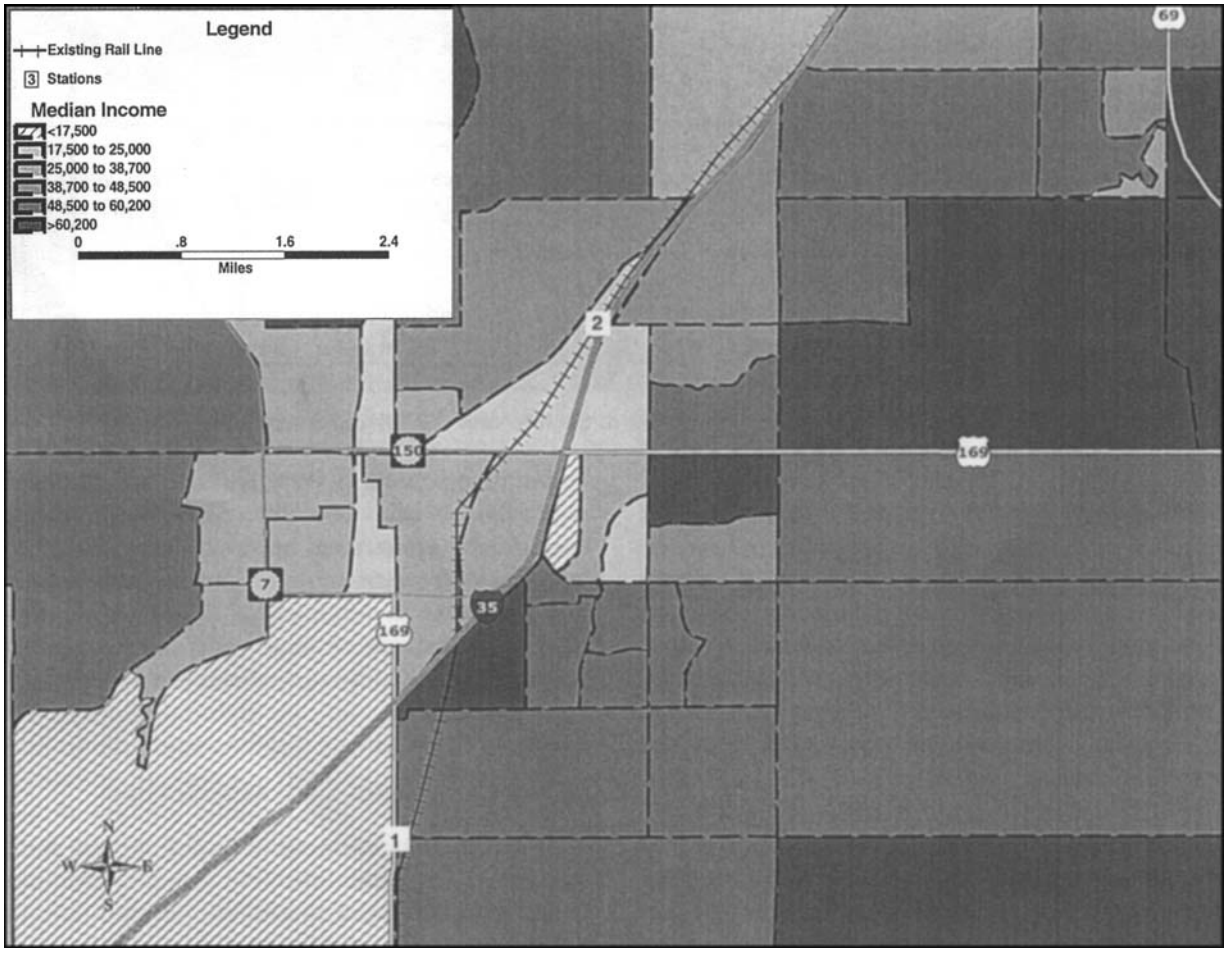


**Figure 3.** Stations 1 and 2 census block income levels, proposed commuter rail project in the Interstate 35 corridor, eastern Kansas/Kansas City, Missouri, area. (Source: 1990 US Census Bureau.)



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**Figure 4.** Stations 3, 4, and 5 census block income levels, proposed commuter rail project in the Interstate 35 corridor, eastern Kansas/Kansas City, Missouri, area. (Source: 1990 US Census Bureau.)

environmental justice issues within the area that might be considered for quantitative EJA.

Census data for 2000 were not available at the time of this study. Income characteristics around the sites were tabulated and characterization of potential "disproportionate" impacts to sensitive populations was conducted for the quantitative EJA as described below. A household of four people with an annual median income of $17,650 in the contiguous United States is considered the low-income/poverty threshold (US Department of Health and Human Services, 2001). The income level of <$17,500 was used as the threshold for low income in this study. It is important to note that median income levels (as reported by the US Census Bureau) were averaged for the blocks in each station's study area (see Table 1), resulting in a mean value used in the statistical analysis. The raw median income levels for each census block are demonstrated in the GIS qualitative analysis (Figures 3 and 4).

## Statistical Method

Data distinguishing sensitive populations near potential transportation routes were not available (with adequate spatial resolution) until GIS applications were implemented in the 1990s. As depicted in Figures 3 and 4, the sensitive population data of this EJA's study area were graphically illustrated using GIS methods. The illustrations alone, however, did not provide sufficient quantitative evidence of "disproportionate" impact information that the Executive Order calls for. Therefore, further assessment was needed to demonstrate whether the proposed In-



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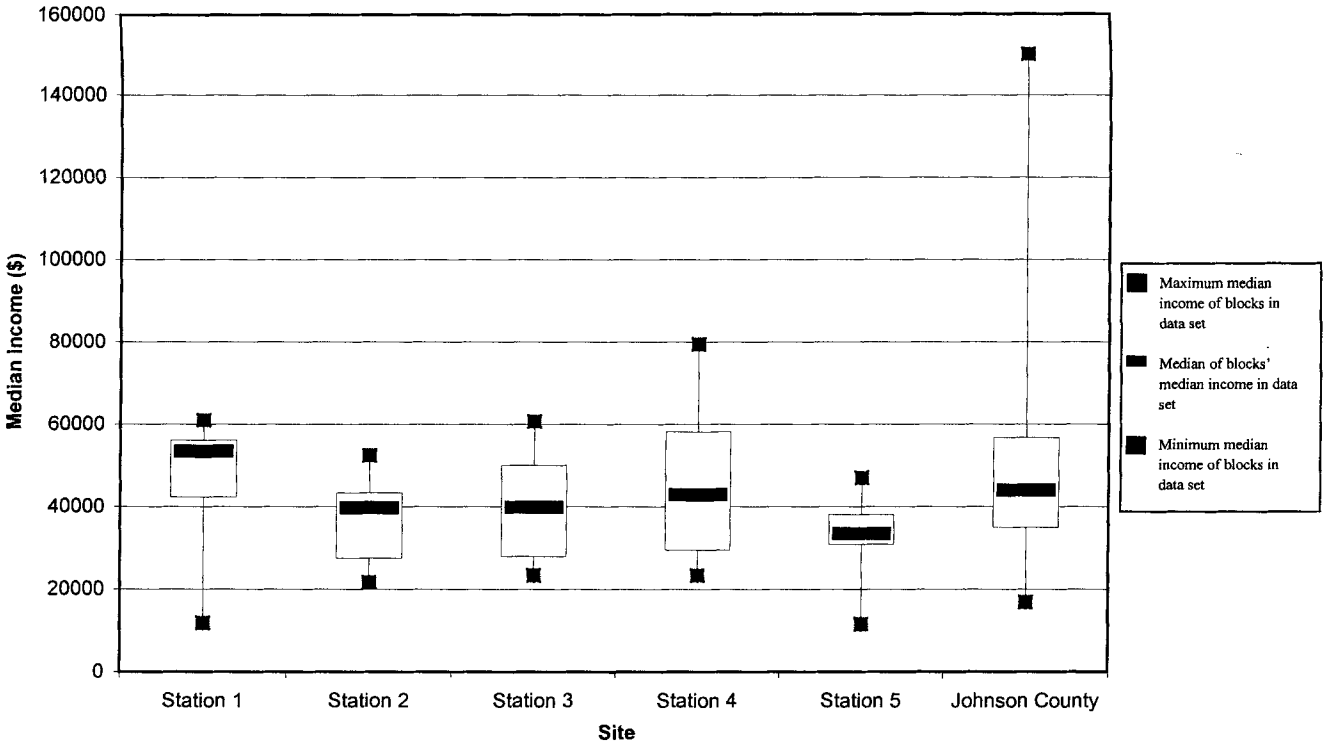


**Figure 5.** Statistical distributions of station and county income, proposed commuter rail project, eastern Kansas/Kansas City, Missouri. This box and whisker plot shows that some data sets of census block income indicate non-normal distributions.

terstate 35 commuter rail project might result in disproportionate impacts.

In the absence of regulatory guidelines for assessing environmental justice issues related to transportation, we developed a quantitative method based on analysis of variance (ANOVA). ANOVA was used to determine if there was a significant difference between the means of median incomes in six data sets (the study areas around each station and the remainder of Johnson County). If the ANOVA test found no significant difference among all data sets, no disproportionate impacts were identified and no further tests would be performed. If the ANOVA test found that there was a significant difference between one or more of the several sets of data, then a further test would be performed to identify which set(s) of data were significantly different from the others.

ANOVA statistics compare the means of an arbitrary number of groups of data. The method involves calculations of the F-statistic; the *p*-value of the F-statistic was used to test the null hypothesis at the 95% confidence level. The ANOVA procedure assumes normal distributions within groups of interest. Because several data sets exhibited non-normal distributions (see Figure 5), log transformation was required to make the distributions more normal. Data transformation was conducted by calculating the natural log of each median income of each census block (see Table 1).

The test hypothesis is an assumption about the characteristics of the populations evaluated that can be supported or rejected by the data. In the context of this study, the null hypothesis states that the study population is "proportionate"; the alternative hypothesis states that the population is "disproportionate." If the ANOVA test finds no significant difference among all sets of data, there is no further test performed. If the ANOVA test finds that there is a significant difference between one or more of the sets of data, then further tests (such as the Bonferroni t-test) are performed to identify which sets of data are significantly different from the control set. The initial ANOVA test serves as a preliminary or screening analysis for follow-up statistical tests needed to identify which sets are significantly different from the control set (Neter, Wasserman, and Kutner, 1990).

## Quantitative EJA Results

Descriptive statistics for the study area are provided in Table 1. As presented, the income groups are sorted accord-



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**Table 2.** Analysis of Variance (ANOVA) statistics for income groups

Transformed data input

| Group number | Blocks | Sum (using natural log, $L_n$) | Mean of $L_n$ ($) | Variance |
|---|---|---|---|---|
| Station 1 | 4 | 42.17246 | 10.54312 (37916) | 0.603212 |
| Station 2 | 6 | 62.79125 | 10.46521 (35074) | 0.128558 |
| Station 3 | 8 | 84.3479 | 10.54349 (37930) | 0.140965 |
| Station 4 | 11 | 117.0951 | 10.64501 (41983) | 0.189938 |
| Station 5 | 15 | 155.6032 | 10.37354 (32002) | 0.109601 |
| Johnson County | 206 | 2209.049 | 10.72354 (45412) | 0.147419 |

Null hypothesis ($H_o$: m1=m2=m3=m4=m5=m6); m = mean.

ANOVA output

| Source of Variation | SS | df | MS | $F_{calculated}$ | *p*-value | $F_{critical}$ |
|---|---|---|---|---|---|---|
| Between groups | 2.309083 | 5 | 0.461817 | 3.037788 | 0.011138 | 2.251028 |
| Within groups | 37.09386 | 244 | 0.152024 | | | |
| Total | 39.40295 | 249 | | | | |

$F_{calculated} > F_{critical}$: Reject the null hypothesis ($H_o$). Data exhibit statistical significance.

ing to station location and were subject to quantitative EJA via the ANOVA statistical method.

The comparison of income groups in the potentially affected study area of station locations (1 through 5) and the general Johnson County population is shown in Table 2. The ANOVA tests the null hypothesis that the means of the median incomes in the six areas are equal (i.e., $H_o$: m1 = m2 = m3 = m4 = m5 = m6), where m = mean.

The probability of obtaining the $F_{calculated}$ = 3.04, if the null hypothesis is true, is 0.011; this value is so low that we conclude the null hypothesis can be rejected. The ANOVA F-test indicates that at least one of the group means differs from the others, and further analysis is required to determine which mean(s) differ.

It should be noted that one of the variances around Station 1 is much higher than those for the other groups. ANOVA assumes that the variances of the different groups are approximately equal. Further work, therefore, based on an alternative research design, would be needed to confirm the results of this test.

**Table 3.** Analysis of Variance (ANOVA) *post hoc* statistics for income groups; *post hoc* test using ANOVA MS = 0.152, with 244 df

Least squares means, and squares error

| Group | Blocks | Least squares mean | Squares error |
|---|---|---|---|
| Station 1 | 4 | 10.54312 | 0.194952 |
| Station 2 | 6 | 10.46521 | 0.159178 |
| Station 3 | 8 | 10.54349 | 0.137852 |
| Station 4 | 11 | 10.64501 | 0.117561 |
| Station 5 | 15 | 10.37354 | 0.100673 |
| Johnson County | 206 | 10.72354 | 0.027166 |

Matrix of pairwise mean differences

| | County | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| County | 0.0 | | | | | |
| 1 | −0.180415 | 0.0 | | | | |
| 2 | −0.258340 | −0.077925 | 0.0 | | | |
| 3 | −0.180040 | 0.000375 | 0.078300 | 0.0 | | |
| 4 | −0.078522 | 0.101893 | 0.179818 | 0.101518 | 0.0 | |
| 5 | −0.3500 | −0.169585 | −0.091660 | −0.169960 | −0.271478 | 0.0 |

It is interesting to note that an apparent low-income population is proximal to Station 1 (see Figure 3). In fact, this large census block (i.e., income level <$17,500) contains very few residents because of the presence of a local airfield and large blocks of rural (non-agricultural) land. As discussed below, however, it is Station 5 that has a mean median income that differs significantly from the other groups.

The Bonferroni t-test method is employed to identify those groups with unequal means (see Table 3). To ensure that the probability is no greater than 5% that something will appear to be statistically significant when there are no underlying differences, each of "m" individual comparisons is performed. Because up to m = 6(6−1)/2, or 15, comparisons were possible between pairs of groups, the Bonferroni adjustment is obtained for each station. The Bonferroni adjustment or *p*-value is then compared to each station's mean difference to identify statistical significance. For this *post hoc* test, only the Station 5 mean difference (0.35) generated a *p*-value (0.014) indicating a significant difference. The Bonferroni result of a statistical difference between Station 5 and the Johnson County background level is also evident in the Figure 5 (box and whisker) plot, as the mean difference (0.35) translates to about a 30% decrease (or about 3.36 standard errors) of the Station 5 mean compared to the rest of the county.



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## Conclusions

It was determined that the sensitive low-income or economically disadvantaged population proximal to Station 5 may be significantly or disproportionately impacted by the development of commuter rail stations at the proposed locations. The other station locations (1, 2, 3, and 4) did not reflect statistically significant results, thereby indicating no disproportionate impacts for these areas. In general, the study findings were similar to results associated with noise and air quality studies that indicated no significant noise or air quality impacts along the majority of the alignment that would disproportionately affect the regional population (Johnson County, Kansas, Public Works, 2001). The statistical results of this study do not include or factor in potential future benefits from economic vitality created as a result of such transportation efficiencies.

In this EJA, a statistical approach was used to quantify disproportionate effects for low-income populations by comparing them (within a one-mile radius of each station location) with the entire potentially disadvantaged population of Johnson County. The quantitative method was used because graphical methods alone often do not provide sufficient evidence of "disproportionate" impacts to affected populations for transportation projects. Figures 3 and 4 graphically depict income level populations in the study area. For example, at first glance Figure 3 depicts a potentially anomalous low-income census block proximal to Station 1. Table 2 and 3, however, provide the results of a quantitative test indicating whether any station population area is potentially impacted disproportionately. As demonstrated in the statistical tests for the low-income parameter (Tables 2–3), there were disproportionate impacts for the Station 5 population in comparison to the general Johnson County population.

Although specific scenarios may lead to some disagreement about what constitutes a disproportionate impact, we conclude that for transportation corridor or facility location assessments, comparison of the study area to the potentially affected, proximal population is appropriate. The statistical EJA method, therefore, can be used in conjunction with traditional graphical methods (such as GIS) to provide the user with a more refined and objective analysis.

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