A PROCEDURE FOR ESTIMATING WORK TRIP RATES OF HOUSEHOLDS IN KUWAIT

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1. INTRODUCTION

Most transportation planning studies include a trip generation component that models trip productions either on the aggregate zonal level or on the disaggregate level of the individual household. Multiple linear regression is the widely used technique to model aggregate zonal trip productions, while the cross-classification analysis is used to estimate trip rates of individual households (1). There have been increasing disenchantment with the use of these conventional techniques. The basic criticism of the regression analysis approach has to do with the loss of variance because of the extremely aggregate nature of these models. The cross-classification analysis has several problems as well. The most important of these problems are related to the absence of a goodness-of-fit measure of performance and the variation in the reliability of trip rates values due to the variation in the number of households available in each cell for calibration. Also there is no well established way to choose among classifying variables or the best groupings for each variable. Another disadvantage relates to the loss of information when all households within each cell are treated similarly (1).

In the Kuwait metropolitan area, cross-classification analysis was used in all transportation planning studies as well as in the transport analysis done during the master plan preparations. Because of the wide variations in household characteristics observed in Kuwait, large number of cross-classification cells were used resulting in cells with low frequencies and subsequently low reliabilities of trip rate estimates (2,3).

This paper shows that the use of the generalized linear models approach can provide a framework through which several improvements over the conventional cross-classification analysis technique could be made. First, it is possible to select among variables to be used in the classification and to examine the best grouping schemes of these variables. Second, trip rates can be estimated from the entire classification and need not depend on the sample of households in a particular cell, thus improving the reliability of trip rate estimates especially for outlying cells. In addition, a goodness-of-fit measure can be used allowing the selection of a particular model form in a consistent manner. The generalized linear model framework allows the use of a linear prediction based on linear combination of explanatory variables. The variables may be continuous, categorical or a mixture of both, (4,5). The single and interactive effects of the explanatory variables could be considered and assessed in a systematic way.

The paper starts by describing the basic characteristics of households in Kuwait which influence work trip generation rates. The impact that selected variables describing household size, structure and economic characteristics has on work trip rates is demonstrated. A background on the generalized linear model framework is presented. The procedure of the use of the general ized linear model approach to model work trip rates for households in Kuwait is then demonstrated. The specific results of the application will be presented in a subsequent paper

2. CHARACTERISTICS OF HOUSEHOLDS IN KUWAIT

The growth history of population in Kuwait is shown in Figure 1. According to the 1985 census, Kuwait population reached 1,697,000 with 680,000 Kuwaitis and 1,017,000 non-Kuwaitis. The two population groups are different in many aspects. The average sizes of Kuwaiti and non-Kuwaiti households are 8.95 and 4.98 respectively. Kuwaiti and non-Kuwaiti households are different in terms of income, car ownership, housing type, social and occupational status of their workers as well as in their spatial distribution within the Kuwait metropolitan area which houses 95 percent of Kuwait's population, (6).

The 1985 census indicates that the proportion of Kuwaitis is only 40.1% with the rest being 37.9% Arabs, 21% Asians and 1% of other nationalities. There are 85,113 Kuwaiti and 142,175 non-Kuwaiti private households. In addition, there are 9441 collective non-Kuwaiti households composed mainly of male workers in camps with a total population in collective households of 227,744, (7).

The household size of the four population groups are significantly different as shown in Figure 2. On the average, Kuwaiti households are 1.5 times larger than Asian households, 1.3 times the size of Arab households and triple the size of households of other nationalities. The proportion of households in the range of 1-4 persons is 15% for Kuwaitis, 20% for Arabs, 40% for Asians and 89% for other households. For larger size households, the figure indicates that the proportions of households of 10 persons or more are 39% for Kuwaitis, 19% for Arabs, 12% for Asians, while none of the households of other origins is more than 6 persons in size.

The age group distribution of members of Kuwaiti and non-Kuwaiti households was discussed previously, (6,8). There is clear domination of the younger-age groups among Kuwaitis. Also, there is imbalance between non-Kuwaiti males and females with almost 160,000 males more than females. This is related to the higher proportion of male adults in non-family situations.

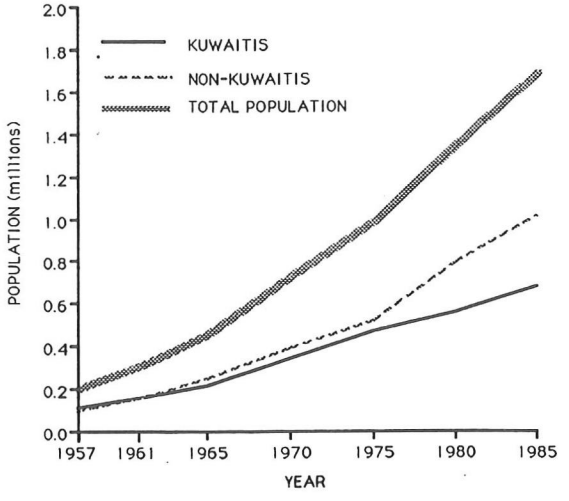


Figure 1 Growth History of Population in Kuwait

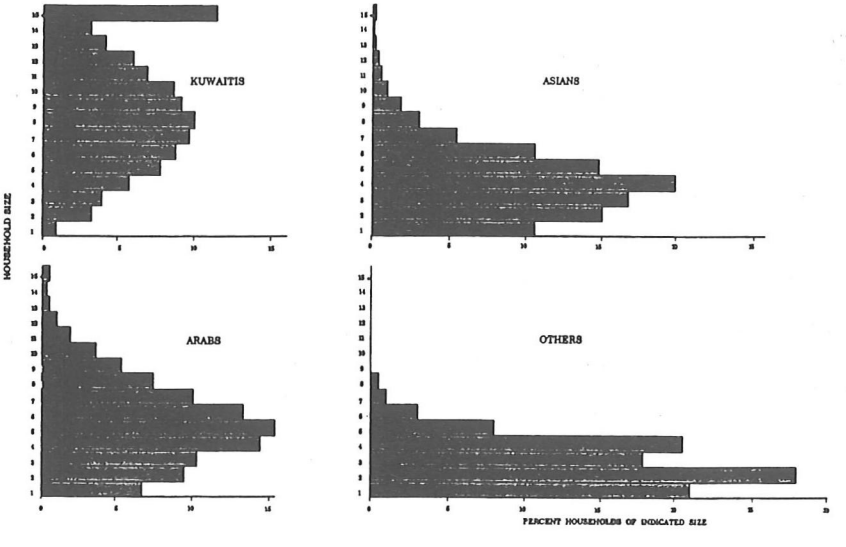


Figure 2 Percent Distribution of Housholds by Size for Different Nationality Groups, 1985

The household size distribution differences among Kuwaitis and non-Kuwaitis demonstrated earlier do not consistently translate into higher number of workers in Kuwaiti households. This is mainly because of the differences in the labor participation rates of Kuwaitis and nonKuwaitis. This is evident from Figure 3 which shows the labor participation rates for Kuwaitis and non-Kuwaitis by age and sex. The low participation rates of Kuwaiti females is clear from the figure. On the average, the participation rates of Kuwaitis are 59.5% for males and 13.8% for females. On the non-Kuwaiti side these rates are 91.6% and 43.7% respectively. Table 1 shows a breakdown of the labor force by nationality groups (Kuwaitis, Arab non-Kuwaitis, Asian non-Kuwaitis and others) along with the labor participation rate for each group. The table shows some variations in the participation rates between different non-Kuwaiti groups specially for females. The labor force participation rates of the Asian group are 98.3% and 76.4% for males and females respectively.

Table 1: Labour Force and Labour Participation Rates for Different Nationality Groups, 1985

Nationality	Population (>15 Years)		Labour Force			Participation Rate (%)		
	Male	Female	Male	Female	Total	Male	Female	Total
Kuwaiti	170,761	179,582	101,607	24,803	126,410	59.5	13.8	36.
Non-Kuwaiti								
Arabs	254,370	145,093	219,989	32,989	252,889	86.4	22.7	63.3
Asians	214,146	94,883	210,338	72,505	282,843	98.2	76.4	91.5
Others	7,856	5,560	6,413	1,831	8,244	81.6	32.9	61.4
Total Non-Kuwaiti	476,366	245,536	436,650	107,325	543,976	91.6	43.7	76.3
Total	647,127	425,118	538,257	132,128	670,385	83.2	31.0	62.5

Figure 4 shows the income distribution of households of different groups as derived from the 1987 home interview survey. Kuwaiti households have an average monthly income of KD 1035 (= US $ 43,500) annually. Arab and Asian households earn a little over half that much while other households have average income about 80% that of Kuwaiti households. Almost, 35% of Kuwaiti households have monthly income in excess of KD 1000 compared to only 7% for non-Kuwaitis.

Car ownership distributions of Kuwaiti and non-Kuwaiti households are shown in Figure 5 where it is shown that Kuwaiti households have average ownership rates of 3 cars. Non-Kuwaiti household groups have ownership rates that vary between 30 and 50 percent of Kuwaiti rates.

Asian households have noticeably low ownership rates - .941 cars/household - and 30 percent of these households have no cars. While there is some correlation between the average income of individual household groups and car ownership, car ownership rates for Kuwaitis are double those of non-Kuwaitis for comparable household incomes. The low car ownership rates of non-Kuwaitis are influenced in addition to income by the restriction on issuing operators license for non-Kuwaitis as a measure to curb traffic congestion.

Figure 6 shows the proportion of Kuwaiti and non-Kuwaiti households according to their housing type in 1987. The figure indicates that 50% of Kuwaiti households live in private villas, 37% in government-built houses (mostly through the National Housing Authority (NHA) and are of the single unit type on relatively smaller lots), while the rest are equally split among apartments, shared villas and other forms of accommodation such as Arabian houses (old style villas). On the contrary, 75% of non-Kuwaiti households live in apartments and less than 4% in villas. The difference in housing types between the two nationality groups reflects differences in income, government policies that restrict the ownership of non-Kuwaitis of real estate properties, but most importantly to the government public housing ownership program. Housing units that have been built through this program are mostly villas.

Kuwaiti male labor force is concentrated in the services (mainly civil service), clerical and professional-technical occupation categories. Non-Kuwaiti male labor force is heavily concentrated in the production worker-labour occupation groups and to a lesser extent in the service and professional-technical groups. Kuwaiti female workers are concentrated in the professional-technical and clerical occupations while more than 65% of the non-Kuwaiti females are employed in the service occupations. Among non-Kuwaitis, more than 80 percent of Asian males are in either the services or production occupations while 88% of Asian females are in the services occupations mainly as domestic workers. These occupation differences suggest that the majority of Kuwaitis work in medium to high salary occupations. Arab non-Kuwaitis work in low to medium wage occupations while Asians work in low wages occupations.

3. TRIP RATES OF HOUSEHOLDS IN KUWAIT

3.1 Household Size

Figure 7 shows the morning work trip rates of households of different sizes and four nationality groups. The figure indicates that Kuwaiti and Arab non-Kuwaiti households have similar trip rates at different household sizes. However, at smaller sizes (1 to 5 person households), Arab households have trip rates that are 15 to 25 percent

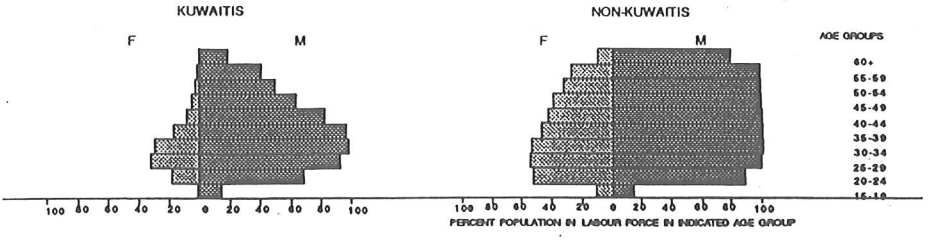


Figure 3 Percent Population in Labour Force by Age and Sex, 1985

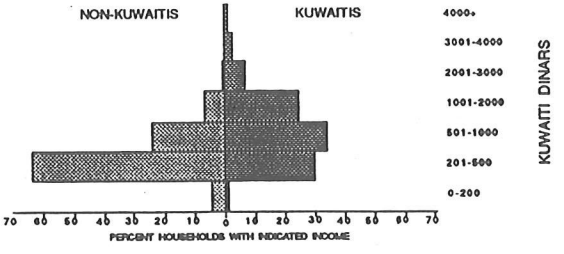


Figure 4 Percent Distribution of Kuwaiti and Non-Kuwaiti Households by Household Monthly Income, 1987

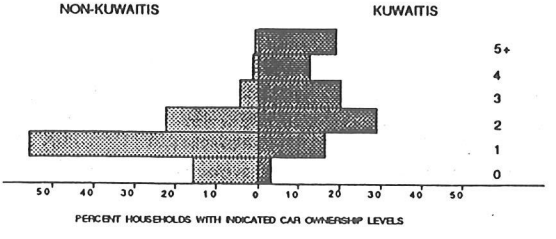


Figure 5 Percent Distribution of Kuwaiti and Non-Kuwaiti Households by Car Ownership Levels, 1987

rates for all household size levels. These households show remarkable increases in trip rates compared to Kuwaiti and Arab non-Kuwaiti households for households larger than 7 persons in size

3.2 Household Structure

Several variables describing households structure, rather than size have been suggested in the literature, (9). Figure 8shows that work trip rates are strongly related to the number of adults in the 18 to 65 age groups for Kuwaitis and non-Kuwaitis. Non-Kuwaiti households produce between 10 to 25% more trips than Kuwaiti households across all levels of adults in individual households. The work trip rate for very large non-Kuwaiti households (10+ persons of age 18-65) is almost double the rate for similar Kuwaiti households.

Another household variable that describes the household structure is the presence of school age children and Figure 9 shows how that variable influences trip rates for the two major nationality groups. Trip rates decrease consistently as the number of persons in the age category of 0-18 years increases with Kuwaitis having relatively higher trip rates.

The impact of the age of household head on work trip rates for Kuwaitis and non-Kuwaiti households is shown below. Kuwaiti households show consistent increases in their trip rates as the age of the head of household increases. With heads of households in the 65+ age category, trip rates show some increase reflecting the extended family structure expected in these cases. Non-Kuwaiti households show less correlation between age of household head and trip rates due to the presence of considerable proportion of households in non-family situations

	Kuwaitis				Non-Kuwaitis			
Age	18-24	25-44	45-64	65+	18-24	25-44	45-64	65+
Trips/h.hold	1.25	1.29	1.39	1.8	1.34	1.35	1.36	1.56

3.3 Car Ownership and Income

Figure 10 shows how household work trip rates vary with car ownership levels for different nationality groups. For similar car ownership levels, Kuwaitis have generally lower trip rates than all other nationality groups. Asian households on the other hand produce almost 80-100 percent more trips compared with other groups for most car ownership levels. Trip rates of Arab non-Kuwaiti households are intermediate in size. The low trip rates produced by Kuwaiti households at different car ownership levels are a result of the extremely high car ownership levels of Kuwaiti households which were shown to be at least double those of other nationality groups.

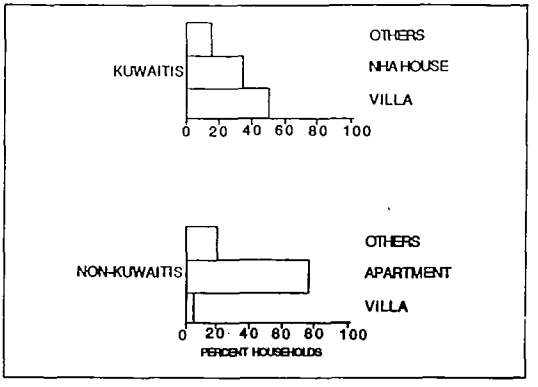
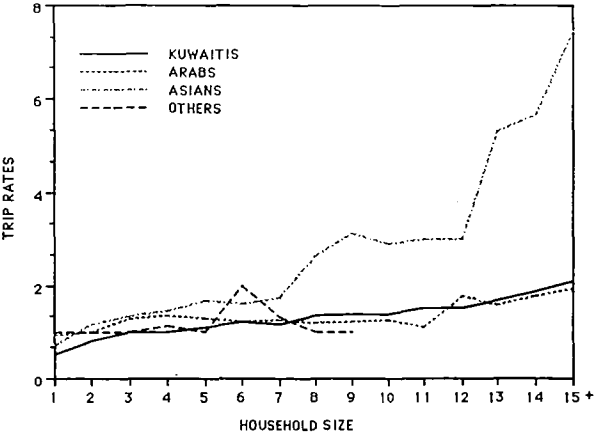


Figure 6
Percent Distribution of Households by Dwelling Unit Type, 1985

Figure 7
Work Trip Rates of Households as Related to Households Size



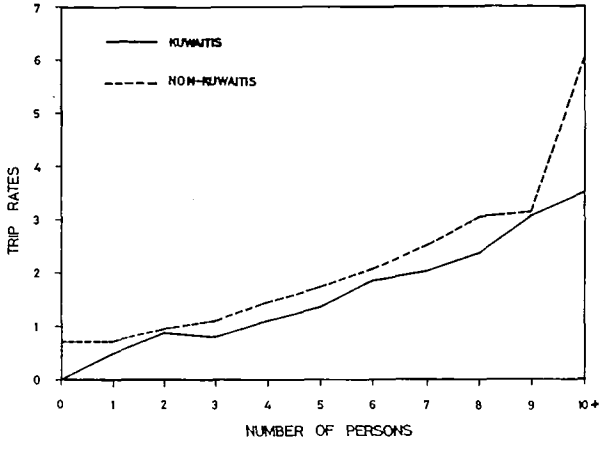


Figure 8
Work Trip Rates of Households as Related to Number of Household Members in the Working Age

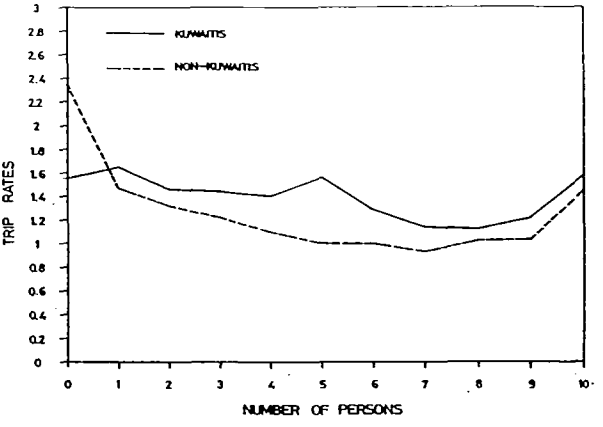


Figure 9
Work Trip Rates of Households as Related to Number of Persons in 0-18 Age Group

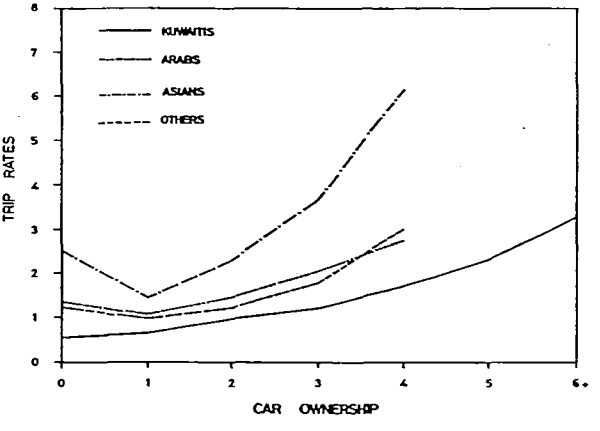


Figure 10
The Impact of Car Ownership on Trip Rates

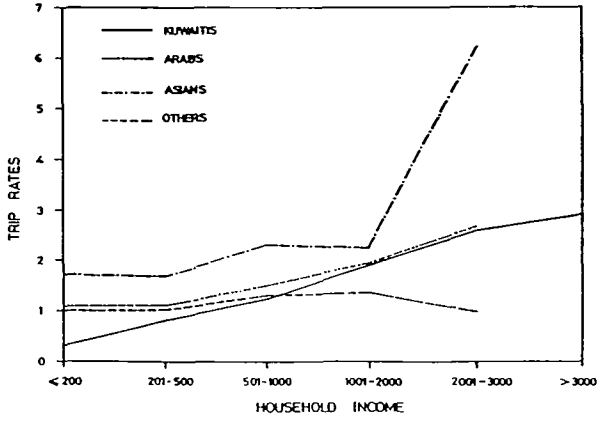


Figure 11
The Impact of Household Income on Trip Rates

Trip rates of individual households of different nationality groups for different income groups are shown in Figure 11. The figure shows that Asian households have consistently higher trip rates across all income groups. This is related to the higher labor participation rates Kuwaitis at low incomes.

3.4 Type of Dwelling Unit

Trip rates of Kuwaiti and non-Kuwaiti households by dwelling unit type are shown below. Among Kuwaitis, those in villas produce more trips. Non-Kuwaitis in apartments and other forms of accommodation (Arabian houses) generate trip rates that are about 10-20% more than Kuwaitis living in a similar housing type. Trip rates of Asian households in apartments and other housing forms are also 50-80% more than other non-Kuwaiti groups.

Kuwaitis			Non-Kuwaitis		
Villas	NHA	Others	Villas	Apartments	Others
1.59	1.27	1.22	1.25	1.34	1.48

3.5 Intensity and Stage of Urban Development

Trip rates of household in zones having low and high residential densities were found to have comparable trip rates. Also it was found that there are no clear differences in trip rates based on the stage of urban development with the exception of the Downtown area. Non-Kuwaiti households in the Downtown area have trip rates noticeably higher than the rest of Kuwait metropolitan area since these households are of the non-family type and are mostly large in size.

4. THE DIFFICULTIES IN USE OF CONVENTIONAL TRIP GENERATION PROCEDURES IN KUWAIT

Aggregate zonal trip generations equations of the regression type are not appropriate to use in the Kuwaiti context. This is mainly because of the extremely aggregate nature of these models as compared to the wide variations in the characteristics of households in individual zones. Besides; the sratified strategy will not totally eliminate the problem of loss of the considerable variance that exists among households even of the same nationality group.

The use of the cross-classification analysis approach, though have several advantages over regression techniques, has its own shortcomings. These were discussed earlier. The most critical of these shortcomings has to do with the variation in the reliability of trip rate values due to the variation in the number of households in each cell during the calibration and the absence of procedures to choose among classifying variables or groupings of each variable. The problem of the reliability of cell estimates of trip rates is very relevant in the Kuwait context. The wide variation among households in the area

would suggest the use of more categories for each classifying variable and most likely more variables in the classification. Within such framework low household frequencies are expected and the reliability of cell estimates are ex-pected to be questionable

5. THE GENERALIZED LINEAR MODELS FRAMEWORK

This section discusses alternative statistical methods of analysis of trip data based on a generalized linear model (GLM) framework, which are likely to be particularly useful in the Kuwait context. Using this approach, models reflecting the dependence of household work trip rates on factors of interest such as household size, household income, number of cars owned, etc., are proposed. The models are then fitted by appropriate techniques such as weighted least squares, or by maximum likelihood if a specific distribution form for work trip rate is assumed. The type of model proposed is flexible, being of the ANOVA type when all factors are qualitative, of the regression type when all factors are quantitative, and of the covariance type when both qualitative and quantitative factors are considered.

To facilitate a more detailed discussion of the statistical models that may be used for work trip data, suppose that we are interested in the effects of say three factors A, B, and C with a, b and c levels, respectively. In the Kuwait context, A might be household nationality group, B might be a grouping of household by size and C a grouping of household car ownership levels. For the population of households in cell (A_i, B_j, C_k) let μ_{ijk} denote the mean and σ^2_{ijk} denote the variance of work trip rates. Primary interest is in the estimation of the $\{\mu_{ijk}\}$. Suppose that a sample of N households is taken which contains n_{ijk} households in cell (A_i, B_j, C_k), where $\sum_i \sum_j \sum_k n_{ijk} = N$. We let Y_{ijkl} $l = 1, 2, \ldots n_{ijk}$ denote the observed numbers of work trips in cell (A_i, B_j, C_k) and let $\bar{Y}_{ijk}$ and S^2_{ijk} denote the observed mean and variance, respectively, for the cell.

The type of statistical analysis to be used will depend on whether or not specific assumptions are made about the distribution of household trip rates within any cell. When no assumption is made, the cell mean $\bar{Y}_{ijk}$ is taken to be approximately normally distributed with mean μ_{ijk} and variance σ^2_{ijk}/n_{ijk}. The approximation will be good provided that n_{ijk} is not very small. Standard ANOVA models for the means can be considered ranging in a hierarchical form from the full interaction model

$$\mu_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\beta\gamma)_{jk} + (\alpha\beta\gamma)_{ijk} \quad (1)$$

to the simple additive model

$$\mu_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k \tag{2}$$

The models are fitted by weighted least squares. The sample variances S^2_{ijk} should of course be examined carefully to see if the assumption of constant variances is reasonable.If it is not, a given model could be fitted by weighted least squares using the empirical weights $\omega_{ijk} = n_{ijk}/S^2_{ijk}$.The ratios $S^2_{ijk}/\bar{Y}_{ijk}$ should also be examined, since a systematic relationship between the variances and means would suggest an analysis of transformed values of household trip rates, such as logarithmic or square root values.

The goodness-of-fit of completing models may be measured by their "deviances" which are the weighted residual sums of squares about the fitted models. For example, the deviance of the model given by equation (2) is:

$$D = \sum_i \sum_j \sum_k \omega_{ijk} (\bar{Y}_{ijk} - \hat{\mu} - \hat{\alpha}_i - \hat{\beta}_j - \hat{\gamma}_k)^2 \tag{3}$$

with $abc - 1 - (a - 1) - (b - 1) - (c - 1)$ degrees of freedom. F-tests using statistics based on the relative changes in the deviances may be used to find as concise a model as possible which adequately represents the data. Use of a concise model has the advantages of providing more precise estimates of the cell true mear trip rates. Different grouping schemes for the variables may also be examined to determine which schemes provide the most sensitive indication of the effects of the variables.

A more refined analysis is possible if assumptions about the distribution of household trip rates within any cell are made. For example if the ratios $S^2_{ijk}/\bar{Y}_{ijk}$ are reasonably close to one, this suggests the use of a Poisson model with:

$$P(Y_{ijkl} = y) = e^{-\mu_{ijk}} . \mu^{y}_{ijk} / y! , \qquad y = 0, 1, .. \tag{4}$$

Since the Poisson mean μ_{ijk} must be positive, a logarithmic model for the means could be used, for example,

$$\log \mu_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k \tag{5}$$

replacing the simple additive model given earlier for μ_{ijk}.

The above Poisson model assumes that the number of work trips for households in a given cell follow a Poisson distribution with the same true mean for all such households. In practice some heterogeneity in the mean trip rates within any cell is likely to exist, so distributions other than the Poisson such as the negative binomial might also be considered. The computational work in fitting these more refined models poses no problems, given the statistical software now available. However, a detailed analysis of the within cell distributions of trip rates does pose some problems, given the large number of cells that might have to be examined and the small numbers of households represented in the extreme cells within the table of classification. This point is particularly relevant in the Kuwait context, because of the need to have a large number of cells to cope with the wide variation in household characteristics.

Some preliminary work on fitting GLM's to the work trip data in Kuwait, using weighted least squares fits, has been made. Results are not reported in this paper. However, the indications are that the GLM approach will provide a very useful framework for informative interpretation of the large body of work trip data collected in the home interview survey made in Kuwait.

6. CONCLUDING REMARKS

The potential difficulties in using conventional trip generation procedurees to estimate work trip end magnitudes for use in the transport planning process in Kuwait were reviewed. These mainly arise because households in Kuwait posses great variations in their size, structure, car ownership, income, occupation status of their employment members and in the type of dwelling unit. The greated difeerences are observed among Kuwaiti and non-Kuwaiti households.

The broad lines of a procedure for estimating work trip rates for households in Kuwait utilizing the generalized linear models framework (GLM) were presented. The GLM approach can provide a framework through which several improvements over the conventional cross-classification analysis techniques could be made. An important advantage of the GLM approach is that the estimated mean trip rate for any cell utilizes a model fit based on data from all cells and not just the data from the given cell, which may be spare. Other advantages are that formal tests of significance may be used to see which individual factors have a real effect on mean trip rates, and that the goodness-of-fit of competing models may be compared statistically.

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REFERENCES

1. Stopher, P. and McDonald, K., (1983), Trip Generation by Cross-Classification: An Alternative Methodology, Transportation Research Record 944, National Research Council, Washington D.C., pp 84-91.

2. Kuwait Municipality, (1978), Kuwait Transportation Study, Final Report, Kuwait.

3. Kuwait Municipality, (1983), Master Plan for Kuwait: Second Review, Final Report, Kuwait

4. Dobson, A., (1983), An Introduction to Statistical Modelling, Chapman and Hall, London

5.McCullagh, P. and Nelder, J.A., (1983), Generalized Linear Models, Chapman and Hall, London.

6. Hutchinson, B.G. and Said, G.M., (1989), Spatial Differentiation, Transport Demands and Transport Model Design in Kuwait, submitted to Transport Reviews.

7. Ministry of Planning, (1987), Annual Statistical Abstract, Central Statistics Office, Kuwait.

8. Said, G.M., (1989), Work Trip Rates and the Socio-Economic Characteristics of Households in Kuwait, submitted to Australian Road Research.

9. Allaman, P. and Tardiff, T. , (1982), "New Approaches to Understanding Travel Behavior", National Co-operative Highway Research Program Report 250, Transportation Research Board, National Research Council, Washington D.C.

10. Baker, R. and Nedler, J., (1978), GLIM Manual (release 3), Numerical Algorithms Group, Oxford, U.K.