Proceedings of the Seventh TRB Conference on the Application of Transportation Planning Methods

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Edited by Rick Donnelly, September, 1999

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Comparing Stratified Cross-Classification and Logit-Based Trip Attraction Models

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Abstract

Trip attraction models constitute half of the trip generation step in traditional 4-step transportation planning models. This means they can play an important role in determining the overall accuracy and responsiveness of such models. Yet it would appear that relatively little has been done to examine potential improvements in practical trip attraction modeling, taking it beyond the basic use of simple linear relationships based on different categories of employment or amounts of floorspace. In particular, the lack of compatibility between stratified trip production models that consider socio-economic differences in trip-making, and regression-based trip attraction models that do not, may severely limit the ability of trip distribution models to correctly allocate workers to jobs.

Recent practical model development work in Cleveland and Phoenix considered two alternative approaches to the modeling of trip attractions. In Cleveland a fairly straightforward cross-classification approach was used, where attraction rates for proportions of workers in different income and car ownership categories were computed using a disaggregate workplace survey. In Phoenix a more novel logit-based approach was used, where proportions of workers by auto ownership and household income were established using the logit formula with utility functions that included various measures of industrial classification and accessibility, using readily available Census Transportation Planning Package (CTPP) data. The intent of both approaches is to appropriately attract the correct number of workers by socio-economic stratification based on the mix and quantity of employment types at the trip destination.

This paper describes the two approaches in detail, considering their theoretical foundations and mathematical properties and discussing some of the practical issues that arise in their development in a United States context. The results of the two models are also examined. It is concluded that these two approaches represent useful advances in the practical modeling of trip attractions beyond the use of simple ratios based on floorspace or total employment, with relative merits that depend on the context of the specific application.

Traditional travel forecasting models consist of four discrete stages, earning the title “the four-step approach”. The first part of the travel demand modeling process, trip generation, consists of two phases, trip production models and trip attraction models. Trip production models estimate the quantity and types of trips using the household as the basic unit of analysis. Trip attraction models, on the other hand, estimate trips based on some measure(s) of employment. The outputs of these two models are connected via the second step of the four-step approach, trip distribution.

Trip production models are often very fine-grained, providing detailed socio-economic information that describes workers characteristics at the household level (i.e. household income, auto ownership, etc.). However, these same variables are often not included in trip attraction models, although these variables are consistently shown to significantly impact work travel behavior, including both trip length and choice of mode. This shortcoming reverberates throughout the model chain, creating distortions in both work trip distribution and mode choice results. Trip distribution models in particular may be severely impacted by this problem, incorrectly connecting workers with jobs, and requiring the application of factors to adjust for these deficiencies. Mode choice models may also be impacted, as transit dependent workers may be incorrectly assigned to non-transit modes.

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This paper describes the two approaches in detail, considering their theoretical foundations and mathematical properties and discussing some of the practical issues that arise in their development. The results of the two models are also examined. It is concluded that these two approaches represent useful advances in the practical modeling of trip attractions beyond the use of simple ratios based on floorspace or total employment, with relative merits that depend on the context of the specific application.

Much of the early research directed towards trip attraction models in the context of the traditional four-step approach has been focused on understanding simple relationships and calculating total trip rates. One of the first papers on trip attraction rates (Shuldiner, 1965) was an exploration of statistical approaches to analyzing trip attraction rates, and a discussion of various input data including floorspace and employment totals. Other research has explored differences in rates with respect to region size (Harmelink, 1966). The Institute of Transportation Engineers (ITE) trip rate manual compiles data on attractions to different types of employment and land-uses, but does not distinguish between trip purposes and is generally not usable for travel model development. Many regions conduct unpublished studies of trip attraction rates, but most of these are geared towards understanding variations in trips attracted to special generators such as airports and recreational areas, and are not adequate for regional model estimation.

A more recent study of trip attraction rates (Arizona Department of Transportation, 1987) analyzed differences in trip rates with respect to establishment type and land-use, ultimately developing rates for five trip purposes and six land-uses. However, this survey did not collect information on worker characteristics such as income and auto ownership. Most recent research exploring household structure and work trips is within the context of activity-based models or trip-chaining models, and is not relevant to this effort.

A lack of data is at least partially to blame for the limited research on trip attraction models. One reason for this lack of data is that workplace surveys are expensive. Given the cost of travel model development, many agencies simply do not have the money to pursue a workplace survey, instead focusing resources on traditional household surveys. Additionally, many of the existing workplace surveys (with the exception of the Cleveland survey) did not collect information regarding worker characteristics. Certainly, the absence of detailed information about workers and visitors to work-places has played a major role in the development of trip attraction models in the United States.

Preliminary Data Analysis

Available data sets for both Cleveland, Ohio, and Phoenix, Arizona, were explored prior to defining model structures for these regions. In Cleveland, a Home-Interview Survey[1], Census data (including both Census Transportation Package and Public Use Microdata Sample) and in particular, a Workplace Survey[2], were accessible. The workplace survey was conducted in spring 1994 in the Greater Cleveland area. A total of 138 employers and 9,689 employees were surveyed. In Phoenix, a Home-Interview Survey and Census data were analyzed. Comparisons of these various data sources are shown below.

Tables 1 and 2 are tabulations of workers by household income and employment type from the Census Public Use Microdata Sample (PUMS) data for both Cleveland, Ohio, and Phoenix, Arizona, respectively. The tables show a relationship between employment type and household income, particularly for workers in the retail sector. Tables 3 and 4 are tabulations of Workplace Survey and Home-Interview Survey data for Cleveland and Phoenix respectively. Note that there are differences in employment type due to both variations in the structure of the different survey instruments as well as data available at the TAZ level in each respective region. Nonetheless, both of these tables show a much stronger relationship between household income and employment type than Census tabulations. A significantly higher percentage of workers lower household income ranges are employed in the retail sector, while a higher percentage of workers in higher income ranges are employed in office or services industries.

It should be noted that the use of employment type in these tabulations tends to obscure the variations in worker household income. Any given employment type contains a myriad of occupations, each with varying wages and salaries. For example, the Service sector shown in Table 3 includes both professional firms such as law offices as well as other, non-professional establishments with lower average incomes. Furthermore, even within a law office, one might expect to find a range of occupations, from administrative assistant to senior partner, each with a commensurate salary.

[1] For further documentation, see “Cleveland Home-Interview Survey” Euclid Consultants, December 1994.
[2] For further documentation, see “Final Report Workplace Survey” Euclid Consultants, December 1994.

The use of household income also distorts the earnings of workers who are members of multiple worker households. This is particularly true of workers in lower-income jobs where two or more members of the household participate in the workforce, thereby increasing household income. An analysis was conducted tabulating personal earnings and worker occupation using Census data (tables not shown). Although these tabulations demonstrated a high degree of correlation, this approach was foregone in favor of a more traditional segmentation strategy, due primarily to available data and expectations regarding the ability to forecast key inputs.

In Cleveland, a cross-classification approach was developed based on the workplace survey, where trip attraction rates were estimated classified by household income, auto ownership, and employment type. In Phoenix, a more novel logit-based approach was developed, where utility functions were estimated to determine the shares of work trip attractions by household income and auto ownership based on employment by type and transit accessibility.

Cleveland Cross-Classification Model

The 1994 Cleveland Workplace Survey was used as the primary source of data for developing work trip attraction rates. The survey collected information on employee travel to and from the workplace, as well as any trips made during business hours. Trip-related information includes an activity code and activity length for up to four stops for each trip tour to and from work, and up to four stops for up to four trip tours made during business hours. The data is organized in a file with one record for each employee (9,672 usable records), and includes household income and the number of automobiles owned per household.

Trip purposes were coded in the survey, consistent with the definitions used in the Cleveland trip production models. The work trip purpose in Cleveland has been expanded to allow the identification of work trips that are part of a complex "chain" or group of trips beyond those in which a worker travels directly between work and home. Further stratification allows the identification of a pick-up\drop-off trip that is made as part of a journey between work and home.

A Direct Work Trip is defined as a work trip that is part of a trip tour which goes directly from home to work, and back to home, with no intermediate stops. It is possible for non-home-based work trips to occur during the day, as long as they are part of trip tours that begin and end at the workplace (for example, a trip to lunch).

A Strategic Work trip involves a pick-up or drop-off of a child at daycare, school, or a baby-sitter. Any trip with one end at work, an intermediate stop involving the pick-up or drop-off of a child, and the other end at home (or vice-versa) was coded Strategic.

Complex Home-Based Work Trips are defined as home-to-work trips that are part of a trip tour involving an intermediate stop at any location for any purpose other than serving the travel needs of a child passenger. For example, a trip from home to work is complex if the return to home leg of the trip tour includes an intermediate shopping stop. The return-to-home tour was coded Non-Home Based-Work from the workplace to the shopping activity location, and Home-Based Shop from the shopping location to home. The workplace would include a Home-based Work Complex trip attraction and a Non-Home Based-Work trip production/attraction.

Trip Attraction Rate Calculation

An expansion factor was applied to each surveyed employee's trips based on the number of sampled employees compared to the total number of employees in attendance on the survey day. This allows the calculation of a trip rate that accounts for employees not in attendance on any given day, resulting in a lower trip rate per employee. Table 5 shows the total number of expanded employees, and Table 6 shows the total number of expanded trips by trip purpose. Trip rates were calculated by dividing the total number of trip attractions per trip purpose (using the expansion factor to calculate total attractions), employment type, and auto ownership/ household income category, by the total number of employees by employment type (including employees not in attendance on the survey day). Area type was excluded from these calculations to ensure an adequate sample size in each employment type and auto ownership/household income cell.

These rates implicitly assume a constant distribution of workers by auto ownership and income group per employment type across all attraction zones. Table 7 through Table 9 shows the Home-Based Work trip attraction rates. The total attractions by auto ownership/household income group per zone is calculated by multiplying total employees per employment sector per zone by the value in each auto ownership/household income cell and summing across columns.

Table 7 shows Direct Home-Based Work trip rates by employment type and auto ownership/household income. The table shows that retail employment generally attracts more low-income trips than service or basic employment; and that as household income increases, the trip rates for service and particularly basic employment increase. Basic employment has the highest trip attraction rate for high-income workers in every auto ownership category.

Table 8 shows Strategic Home-Based Work trip rates by employment type and Auto Ownership/Household Income category. There is a very low trip rate in the 0 Auto category, because 29 trips were made by employees who reported 0 vehicles owned, yet made a strategic trip. *24 of these trips were drive alone*, suggesting the use of a non-household automobile. This table also shows a much lower trip rate for the retail sector than other employment types. This may be due to the presence of younger employees who do not have children.

Table 9 shows Complex Home-Based Work trip attraction rates. They generally follow the same pattern as Direct Home-Based Work trip rates; the retail sector has a higher trip rate for low-income workers, and the basic sector has a higher trip rate for high-income workers.

Phoenix Logit Share Model

Phoenix PUMS data and the home-interview survey both suggest a strong relationship between household income and employment type. Retail, office, and industrial employment all respond to changes in household income, although to varying degrees depending on the data source used. This analysis supports the conclusion that it is possible to develop a model of work trip market segmentation at the trip attraction end based on the employment types currently predicted by MAG.

The Census Transportation Planning Package Part 8 reports workers by household income and auto ownership, separately, by workplace TAZ. Using two-dimensional matrix balancing, it was possible to create a reasonable estimation of workers by *both* auto ownership *and* household income, at the attraction zone level. To this data set was appended MAG 1990 estimates of employment by employment type, and set of accessibility indices and urban form variables. This data set was used as a basis for exploring model formulations and selecting a final model.

The first models explored were a set of linear regression models, whose dependent variables were workers by each income and auto ownership classification, and whose independent variables were measures of employment by employment type. A variety of urban form and accessibility indices were also explored. Many of these variables involved the use of floating zones, where the total value of some variable (for example, office employment) was aggregated for all zones within a certain distance of a zonal centroid. Floating density variables were also computed based on the total area within a certain distance of zonal centroid.

There are several practical and theoretical problems with the regression approach, most of which stem from the fact that there is one regression-based model for each market segment. In an entirely disaggregate model, this could result in a total of 12 market segments (Three categories of auto ownership and four categories of household income). Besides the considerable work effort required to estimate 12 regression models, a more serious problem is the independent nature of the models, for both model estimation and application.

In model estimation, the coefficients on each variable are estimated entirely independently. That is, the coefficient on employment type for one market segment is not estimated simultaneously while considering the presence of workers in other market segments at the same attraction zone. A related problem is that the value of a coefficient within one market segment regression model is not easily comparable to the coefficient for another market segment.

The model is also predicated on the absolute mix of employment in the base year. Future employment estimates may vary considerably, and as a result, changes in the mix of employment (not total employment) in an attraction zone could create a change in the number of workers predicted by one market segment regression model and no change in workers predicted in another markets segment.

In application, for any attraction zone, there is no constraint on the total number of workers predicted by summing the results of the models. The models could very well over or under predict total workers and workers by market segment.

For the reasons stated above, the regression formulation was rejected in favor of a simultaneous form, the logit share model. The model predicts probabilities of workers by each market segment based on the mix of employment by type (represented by percent of employment by employment type by zone), and also has the potential to consider urban form and accessibility variables.

The important distinction between the logit share model and separate regression models is that the share model coefficients are estimated simultaneously, and the value of the coefficients can easily be investigated to determine if their value moves in a logical direction with respect to household income and auto ownership. A selection of the estimation runs are shown in Table 10 and shown below.

Run 1 is a base run. There are coefficients on each employment type. For this run, the total number of employees by employment type was used, instead of percent of total employees by employment type. The run resulted in mostly significant coefficients (insignificant variables are shaded). Further, the values of the coefficients are logical with respect to market segments. The coefficient on office employment tends to increase in value with respect to household income, indicating that this employment type tends to attract higher income workers. Conversely, the coefficient on retail employment tends to decrease with respect to household income, indicating that retail employment tends to attract lower income workers. These findings are entirely consistent with the data reviewed above. No transit accessibility or urban form variables were attempted in this run. Run 2 dropped insignificant variables from Run 1.

Run 3 added employment density as an urban form variable, in an attempt to explore the effect of cbd employment on market segmentation. Employment density was found to be highly significant, with logical coefficient values with respect to household income and auto ownership; the coefficients decrease as household income increases, which indicate that more dense urban environments, such as the central business district, tends to attract more wealthy workers.

Run 4 substituted percent of employment by employment type for total employees by employment type. This has the effect of reducing the value of the urban form coefficients, and changing the values of some of the other coefficients, but they continue to behave in a logical manner (see Run 1 above). Run 5 dropped the insignificant coefficients from Run 4.

Run 6 added another urban form variable, office density, to the model formulation. This variable was explored to isolate the effect of 'high-rise' office buildings on the attraction of wealthy workers. The coefficient was insignificant for all but the highest income stratification, perhaps due to the relatively limited downtown office buildings in the Phoenix region. Run 7 dropped the insignificant variables from Run 6, which results in a model that will result in more workers in the highest income markets segment attracted to denser office environments, all other things being equal.

Run 8 explored transit access to regional households (30 minute threshold, as used in the auto ownership model). This variable is significant and moves logically with respect to the auto ownership market segment. All other things being equal, a zone with transit access to a relatively greater proportion of regional households will attract workers in lower auto ownership households.

Run 9 is the final run shown. It is exactly as Run 8, with a slightly different definition of employment density (total employment/total area in sq. mi.)/1000. The Rho-squared with respect to zero is 0.3545; the Rho-squared with respect to constants is 0.0018.

Comparison of Approaches and Conclusion

The trip attraction models can be compared by converting each to percent of total attractions by employment type, auto ownership and household income. Table 12 shows the percent of Home-Based Work Trips for Cleveland Ohio by employment type, auto ownership, and household income. This table was calculated by dividing the total HBW trips by employment type, auto ownership and income by the total number trips by employment type. A number of stratifications were collapsed for purpose of comparison to Phoenix.

The probabilities by auto ownership and income are shown for Phoenix, Arizona, in Table 12 Each column represents a sample zone in which 100% of the zone employment is in either Industrial, Office, or Retail.

The tables show some similarities, as well as point to some differences, in the socio-economic stratification of workers in each metropolitan area. It is evident that there is a higher percentage of workers with no autos in Cleveland compared to Phoenix. The comparison also demonstrates that there are a higher percentage of lower-income workers in Phoenix than in Cleveland. Additionally, each region has the highest percentage of workers in the highest income and auto ownership category.

There are differences in the variation of workers by auto ownership and income estimated for each employment category. There is more significant variation in the Cleveland rate-based model compared to the Phoenix model, particularly with respect to the stratification of Retail employees compared to either Basic or Service workers. This is due to the relatively large bias constants in the Phoenix model, which offsets the explanatory power of the coefficients for each employment category. The rate-based model developed for the Cleveland region requires the balancing of trip attractions to productions, to achieve the correct numbers of total attractions by trip purpose and stratification. However, the balancing mechanism will preserve or intensify differences in trip rates, while the bias constants in the logit model may tend to dilute such differences.

Certainly, the employment categories used in each region tend to obscure differences in worker characteristics. Other research has shown a much greater amount of variation when comparing worker occupation instead of the more generic employment type, and even greater variation when analyzing personal income versus household income. However, the ability of most planning agencies in the United States to provide future estimates of employees by occupation, and locate such activities in space, is limited at best. Given the constraints in the description of employment at the TAZ level, the models developed for Cleveland and Phoenix are a valuable advancement in the modeling of trip attractions.

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Table 1: Percent of Workers by Employment Type (Industry) and Household Income, Cleveland, Ohio PUMS

Employment Type	Household Income ($000's)			
	0 -15	15 - 30	30 - 50	50 +
Retail	25.5%	19.7%	17.4%	15.1%
Service	46.2%	42.2%	40.3%	44.6%
Industry	19.5%	26.6%	28.5%	26.6%
Trans/Wholesale	7.2%	10.2%	12.4%	12.4%
Agriculture	1.6%	1.4%	1.3%	1.3%
Total	100.0%	100.0%	100.0%	100.0%

Table 2: Percent of Workers by Employment Type (Industry) and Household Income, Phoenix, Arizona PUMS

Employment Type	Household Income ($000's)				
	0 - 15	15 - 25	25 - 35	35 - 50	50 +
Retail	24.8%	21.6%	19.7%	17.8%	15.5%
Service	47.5%	46.7%	46.1%	46.0%	50.2%
Industry	15.2%	18.6%	19.8%	21.1%	19.2%
Trans/Wholesale	6.7%	8.7%	10.8%	12.0%	12.8%
Agriculture	5.9%	4.4%	3.6%	3.1%	2.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Table 3: Percent of Workplace Survey Workers by Employment Type and Household Income; Cleveland, Ohio

Employment Type	Household Income ($000's)			
	0 - 15	15 - 30	30 - 50	50 +
Basic	29.1%	34.2%	36.4%	43.0%
Service	36.8%	47.2%	47.8%	46.5%
Retail	34.1%	18.6%	15.8%	10.5%
Total	100.0%	100.0%	100.0%	100.0%

Table 4: Percent of Home-Interview Survey Workers by Employment Type and Household Income; Phoenix, Arizona

Land Use Code (MAG)	Household Income ($000's)				
	0 - 15	15 - 25	25 - 35	35 - 50	50 +
Retail	21.6%	16.9%	18.2%	14.8%	14.1%
Office	38.9%	39.3%	40.3%	46.3%	54.9%
Industrial	10.4%	12.7%	15.1%	11.8%	6.9%
Public	12.1%	16.6%	14.5%	14.9%	14.5%
Other	1.9%	1.6%	2.1%	2.8%	1.2%
Residential	15.1%	12.8%	9.9%	9.4%	8.4%
Total	100.0%	100.0%	100.0%	100.0%	100.0%

Table 5: Expanded Employees by Employment Type and Area Type

Employment Type	Area Type			Total
	Suburban	Fringe	CBD	
Basic	3643	2693	4311	10647
Service	3171	4401	8696	16268
Retail	1243	2777	359	4379
Total	8057	9871	13366	31294

Table 6: Total Expanded Trips by Trip Purpose

Trip Purpose	Frequency	Percent
Direct	26577	37.37
Complex	10847	15.25
Strategic	2862	4.02
Total	71121	100

Table 7: Direct Trip Rates

Auto Ownership	Household Income	Employment Type Basic	Service	Retail
0 Autos	0-15	0.006	0.015	0.031
	15-30	0.017	0.025	0.023
	30-50	0.013	0.011	0.006
	50 +	0.015	0.010	0.003
1 Auto	0-15	0.012	0.018	0.039
	15-30	0.062	0.060	0.070
	30-50	0.073	0.053	0.021
	50 +	0.065	0.045	0.013
2 Autos	0-15	0.007	0.004	0.025
	15-30	0.042	0.031	0.064
	30-50	0.117	0.110	0.141
	50 +	0.314	0.206	0.102
3+ Autos	0-15	0.004	0.001	0.013
	15-30	0.015	0.011	0.030
	30-50	0.056	0.031	0.073
	50 +	0.164	0.139	0.166
Total All Autos, Income		0.982	0.770	0.820

Table 8: Strategic Trip Rates

Auto Ownership	Household Income	Employment Type Basic	Service	Retail
0 Autos	0-15	0.000	0.002	0.001
	15-30	0.000	0.000	0.000
	30-50	0.002	0.002	0.001
	50 +	0.002	0.002	0.000
1 Auto	0-15	0.002	0.002	0.004
	15-30	0.006	0.014	0.002
	30-50	0.005	0.006	0.003
	50 +	0.003	0.003	0.001
2 Autos	0-15	0.000	0.001	0.005
	15-30	0.003	0.004	0.010
	30-50	0.014	0.019	0.013
	50 +	0.037	0.023	0.012
3+ Autos	0-15	0.000	0.001	0.000
	15-30	0.002	0.000	0.002
	30-50	0.003	0.003	0.006
	50 +	0.018	0.009	0.016
Total All Autos, Income		0.097	0.091	0.076

Table 9: Complex Trip Rate

Auto Ownership	Household Income	Employment Type Basic	Service	Retail
0 Autos	0-15	0.001	0.001	0.013
	15-30	0.003	0.006	0.006
	30-50	0.006	0.002	0.003
	50 +	0.005	0.006	0.001
1 Auto	0-15	0.004	0.003	0.009
	15-30	0.025	0.027	0.028
	30-50	0.027	0.030	0.012
	50 +	0.021	0.015	0.004
2 Autos	0-15	0.002	0.005	0.005
	15-30	0.009	0.017	0.019
	30-50	0.049	0.039	0.054
	50 +	0.125	0.089	0.044
3+ Autos	0-15	0.000	0.001	0.004
	15-30	0.005	0.005	0.011
	30-50	0.022	0.022	0.039
	50 +	0.082	0.062	0.057
Total All Autos, Income		0.386	0.330	0.309

Table 10: Sample Trip Attraction Regression Estimation Runs, Auto 1 Income 1

Variables	Run1		Run 4		Run 11		Run 20		Run 35		Run 39		Run 44	
	t	coeff	T	coeff	t	Coeff	t	coeff	t	coeff	t	coeff	t	coeff
Daily Park						8.27								
Industrial Employment	11.2	0.016	6.5	0.01	6.8	0.011	11.1	0.015	10.8	0.015	11.1	0.015	10.9	0.015
Other Employment	9	0.033	7.4	0.027	7.9	0.029	8.5	0.031	8.5	0.031	7.8	0.028	7.7	0.028
Office Employment	11.9	0.023	10.3	0.02	10.5	0.029	11.7	0.022	9.7	0.021	11.4	0.021	10.6	0.020
Public Employment	13.1	0.036	9.8	0.029	11	0.032	12.9	0.036	12.7	0.035	12.4	0.034	12.5	0.034
Retail Employment	17.9	0.061	13.5	0.05	9.3	0.038	16.2	0.057	17.1	0.060	10.6	0.043	10.2	0.041
Employment Density					-4.8	-0.152								
Employment Density 2 *														
% Employed Area			6.5	0.599	6.6	0.634								
HH Density					5.9	0.606								
Mean HH Income / Wt. Avg					-0.2	-0.227	3.6	3.769						
% Residential Area														
Population Density														
Office Density														
One Mile Total Emp.									1.9	0.000				
Two Mile Total Emp.														
Five Mile Total Emp.														
Seven Mile Total Emp.														
One Mile Pop Density											8.3	0.391		
One Mile HH Density														
One Mile Income Percent														
One Mile Emp. Density														
Two Mile Pop Density														
Two Mile HH Density													8.8	1.139
Two Mile Income Percent														
Two Mile Emp. Density														
Five Mile Pop Density														
Five Mile HH Density														
Five Mile Income Percent														
Five Mile Emp. Density														
Seven Mile Pop Density														
Seven Mile HH Density														
Seven Mile Income Percent														
Seven Mile Emp. Density														
R^2	0.581		0.595		0.615		0.585		0.582		0.603		0.605	
F	351		310		224		298		294.0		320.0		323.0	

Table 11: Estimated Proportion of Total HBW Trip Attractions by Auto Ownership, Household Income, and Employment Type, Cleveland Ohio

Auto Ownership	Household Income	Employment Type: Basic	Service	Retail
0 Autos	All	4.78%	6.88%	7.30%
1 Auto	0-15	1.22%	1.93%	4.32%
	15-30	6.35%	8.48%	8.30%
	30+	13.25%	12.76%	4.48%
2+ Autos	0-15	0.88%	1.09%	4.32%
	15-30	5.19%	5.71%	11.29%
	30+	68.33%	63.15%	59.99%
Total All Autos, Income		100.00%	100.00%	100.00%

Table 12: Estimated Proportion of Total HBW Trips by Auto Ownership, Household Income, and Employment Type, Phoenix Arizona

Auto Ownership	Household Income	Employment Type: Industrial	Office	Retail
0 Autos	All	2.27%	2.34%	2.67%
1 Auto	0-10	4.35%	4.22%	5.67%
	10-25	8.60%	9.13%	10.42%
	25+	12.45%	11.93%	9.62%
2+ Autos	0-10	2.77%	2.95%	4.81%
	10-25	8.51%	9.07%	11.93%
	25+	61.05%	60.35%	54.88%
Total All Autos, Income		100.00%	100.00%	100.00%

Iterative Activity Re-Assignment

Joerg Esser, *Santa Fe Institute*; and Kai Nagel, *Los Alamos National Laboratory*

Abstract

Traffic flows in transportation systems are driven by travel demands, which in turn result from individual activity patterns characterized by activitiy type (e.g. working, shopping, sleeping), location and time. These patterns are based on individual decision processes, where individuals take into consideration which traffic conditions they encountered in the past (e.g. they adjust their shopping time and/or location according to traffic jams which occurred during the last days). In order to reproduce realistic traffic in a laboratory environment (e.g. in a simulator for transportation planning purposes), these interactions between individual decision processes and resulting traffic flows need to be considered.

We present an approach for iterative activity assignment based on feedback from a microscopic traffic simulation. The investigations were carried out within the framework of the TRANSIMS (TRansportation ANalysis and SIMulation System) project at Los Alamos National Laboratories, for which the Portland/Oregon region is currently used as testing field: Demographic data, which provide detailed information about locations and types of households and working opportunities, serve as starting point. As an exemplary scenario we focus on home-to-work trips, which make up the most significant portion of the morning rush hour. Each worker is allocated to a randomly chosen working opportunity, while the probability to pick a particular working place is proportional to its attractivity in terms of travel time distance between household and working place location. At this point, information about individual travel time acceptance is needed, i.e. information about in how far higher travel times are more inconvenient for people. We extract this information from census data, which give the travel time distribution for home-to-work trips, in combination with the working place availability given by land use data and the link travel times resulting from the simulation. Once worker are assigned to working places, route plans are generated for all trips and, finally, the resulting traffic flows are generated by running a microscopic traffic simulator. By this, feedback about congestion, which results from the current home-to-work trips, is provided. In the next step, workers are re-assigned to working places based on the last simulation feedback (i.e. link travel times after the last simulation run). This re-assignment procedure is repeated till the resulting traffic patterns remain constant (within random fluctuations) between different assignment iterations.

Our investigations show that average travel time acceptance data can be extracted from appropriate census data using traffic simulation feedback and that activity re-assignment is computationally feasible with a resolution down to individual travelers for realistically sized transportation systems.

Maine Statewide Travel Demand Model

Dan Krechmer and Tim Case, *Parsons Brinckerhoff Quade & Douglas, Inc*.; and
Bill Croce, *Maine Department of Transportation*

Abstract

This presentation described the key features of the Maine Statewide Travel Demand Model, which was developed under the guidance of the Maine Department of Transportation (MDOT), with funding from both MDOT and the Maine Turnpike Authority. The presentation featured two innovative elements of the project: use of geographical information systems (GIS) and incorporation of recreational travel in the model.

The model will be used by MDOT, the MTA and regional planning agencies to forecast future travel on major roads Min the State, to evaluate the impact of proposed major capital improvements, and to provide key inputs for required air quality analysis. Applications already completed or underway include the development of forecasts for years 2006 and 2015 to evaluate the air quality impacts of a proposed widening of 30 miles of the Maine Turnpike and forecasts of travel on a proposed new East-West high-way across the northern part of Maine. The model was developed using the TRIPS modeling package (MVA Systematica) which is the Maine DOT statewide standard.

A survey was conducted on the Maine Turnpike during a weekday and a Sunday in August in order to obtain data on travel patterns and traffic mix. Recreational travelers were asked not only about their current trip but also about their entire itinerary while in Maine. An important and unique aspect of the trip generation model is that it accounts for tourist trips produced in Maine by out-of-state residents. Production rates were developed and applied for motels, hotels, campgrounds and recreational homes to account for the increase in summertime travel. These additional units add 20% to 25% to the additional occupied housing stock during the summer months and are thus critical to accurate travel forecasts. Several sources were used to develop trip rates including the Turnpike surveys, previous local surveys and models, rates from other statewide models and ITE vehicle trip rates.

The statewide network is being built using ARCView and ARCInfo Geographic Information System (GIS) software to combine statewide network developed by Maine DOT with four existing Metropolitan Planning Organization networks in Portland, Lewiston-Auburn, Bangor and Portsmouth, NH-Kittery, ME. Link codings were standardized between the networks as they were incorporated into the statewide model. The network has approximately 1,500 zones and over 10,000 roadway links. One of the advantages of using the GIS software to develop the network is that many of the key links, including those in the Interstate system, have an accurate geographic representation.

Separate models were developed for both goods movement and mode split. These are primarily "off-network" models, which can be incorporated more fully into the statewide model in the future.

Peak Spreading Models: Promises and Limitations

Chuck Purvis, *Metropolitan Transportation Commission*

Abstract

This paper discusses a new time-of-day departure time choice model, or “peak spreading” model, as developed for the San Francisco Bay Area. The model is a simple binomial logit choice model with the choices of AM peak (two-hour) period departure and non-AM peak period departure. The choice is applied to daily home-to-work auto person trips. This home-based work departure time model is estimated using data from the 1990 Bay Area household travel survey, using data variables such as free-flow and AM peak period congested travel time, trip distance, household income, and dummy variables for bridge crossers, carpooling and retail employment. Highway assignments were calibrated and validated against 1990 daily and peak period traffic volumes and peak period speeds.

The problems with using this model in future year forecasts are discussed. This simple peak-spreading model has a tendency to divert trips from the peak period to the shoulders of the peak period due to increased congestion levels. The result is that the peak period traffic volumes are sometimes lower than the peak shoulder period traffic volumes, yielding too fast speeds in the peak period and too slow speeds in the shoulder periods. This is our “snow plow” effect, with traffic piling up on the shoulders to allow traffic to flow during the peak period. The quick fix to this problem was to prepare four-hour AM peak period traffic assignment based on peaking factors derived from household travel surveys. The slower of the two-hour and four-hour AM peak period assignments are used to feed back to all mode choice models for purposes of forecast equilibration.

Other logit departure time models have been estimated and are discussed. They include multinomial choice models (peak period, shoulder period, off-peak period) and binomial choice model (peak period, shoulder period) based on four-hour AM peak auto person trips.

The purpose of this paper is to document new time-of-day choice models developed by staff of the Metropolitan Transportation Commission (MTC). MTC is the metropolitan planning organization for the nine-county San Francisco Bay Area. A review of the literature of time-of-day choice models is included in reference (1).

Background MTC research on time-of-day travel patterns is included in a 1990 MTC household travel survey report (2). Detailed MTC memorandum discussing the estimation, validation and application of the home-to-work departure time choice models is included in two technical memoranda (3, 4). In terms of general peaking characteristics, 66 percent of the vehicle trips in the AM peak period (0630-0830 AM) are home-based work trips. In comparison, just 40 percent of the vehicle trips starting in the PM peak period (0400-0600 PM) are home-based work trips. In the Bay Area, the PM peak period has about 26 percent more vehicle trip starts than the AM peak period.

Traditional time-of-day factors (post mode choice, pre-assignment) are shown in Table 1. These convert daily, production-attraction format person trip tables by trip purpose and travel mode into AM peak hour vehicle trips. These factors are typically derived from local household travel surveys. Important to note are the higher peaking factors for home-based work share ride trips compared to home-based work drive alone trips. This suggests that drive alone commuters have more flexibility in work time arrival compared to formal carpools. It is also interesting to note the gradual "spreading of the peak" represented by these declining home-to-work trip factors between the 1965 and 1990 surveys. The major problem with this traditional approach is that these constant factors can't be used to simulate any "spreading of the peak" and will tend to over-estimate congested travel times in future year scenarios.

The new "hybrid" approach to peak trip factoring is shown in Table 2. In the new MTC travel model system, traditional peaking factors are used to convert daily non-work trips into peak period vehicle trips; and a new, binomial logit choice model is used to split daily home-to-work trips into trips that start during the AM peak period; and trips that don't start during the AM peak period. Also shown in Table 2 are the four-hour peaking factors that are used to complement the two-hour traffic assignments.

The final binomial choice home-to-work departure time choice model is provided in Table 3. The shared ride dummy variable is positive and reflects the higher probability of carpoolers to start their travel during the peak periods. The second degree polynomial of auto distance reflects the tendency of very short distance and very long distance commuters to begin their commute outside the two-hour AM peak period. The negative coefficients for the "bridge crossing dummy" and the "San Francisco Oakland Bay Bridge crossing dummy" reflect the high propensity of bridge users to begin their commute outside the two-hour AM peak period. And lastly, the "retail industry" variable indicates the higher probability of retail workers to begin their commute after the 0630-0830 AM peak period.

One of the major concerns with using this departure time choice model was the potential to reduce the peak period demand, thereby increasing traffic during the "shoulder" hours of the commute period (0530-0630 and 0830-0930 AM). In extreme cases, shoulder hour travel demand would be higher than the peak period travel demand, yielding an "inverted" greater peak period, or a "snow plow" effect (traffic volumes and travel times that are higher in the peak shoulders than during the center of the peak period!)

This "snow plow" effect is summarized in Figure 1. This scatterplot shows the MTC regional highway links with their two-hour congested speeds on the x-axis, and the four-hour congested speeds on the y-axis. In normal circumstances, four-hour speeds are faster than two-hour speeds. This is represented as links above the diagonal line. The abnormal situation occurs when the four-hour speeds are slower than two-hour speeds, represented by the data points below this diagonal line. For example, some links show a 50 mile per hour speed during the two-hour peak period, yet a 15 mile per hour speed during the four-hour peak period. This is not an acceptable feature. This inverted speed, or "snow plow" phenomena wasn't that extensive with only 4 percent of the 22 thousand links in the MTC high network exhibiting this trait.

The “quick fix” that MTC included in future year forecasts was to feed back the lower of the two travel speeds into mode choice, the reasoning being that the lower speed is a more accurate and believable reflection of the AM peak two-hour peak (and that the MTC mode choice models were estimated using AM peak two-hour travel times and costs!)

Regional forecasts using this new peak spreading model is shown in Table 4. This table shows the peak versus non-peak choice for auto person trips for 1990 through 2020, stratified by vehicle occupancy level. Overall the peak share of daily home-to-work auto person trips are forecasted to decrease from about 56 percent of trips in 1990 to about 53 percent of trips by the year 2020. On a corridor specific level the expectation is for a much wider variation due to direction and intensity of the commute. Between 1990 and 2020 the prediction is for a 33 percent increase in the amount of home-to-work vehicle trips starting in the AM peak period; and a 47 percent increase in home-to-work vehicle trips starting outside the AM peak period. This is a very significant change from past practice!

Other time-of-day models have been tested in the Bay Area. Multinomial departure time choice models that have the peak, the shoulder of the peak, and the other hours of the day as a three-alternative model are shown in Table 5. On the other hand, non-work departure time choice models were attempted but none were successful.

The last point to be made is the importance of peak spreading models used in conjunction with steeper speed-flow models. It is very important to include some sort of peak spreading models when using steeper speed-flow models, or the analyst may end up exaggerating the shifts to other travel modes, or exaggerating future congestion levels. Peak spreading models are a great tool to moderate congestion forecasts in over-saturated situations, and are a practical extension to traditional trip-based “four step” travel model systems.

References

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3. Purvis, Chuck. “Disaggregate Estimation and Validation of Home-to-Work Departure Time Choice Model: Technical Memorandum HBWDT #1” Metropolitan Transportation Commission, Oakland, California, December 5, 1996 [memorandum].
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Table 1: Conventional Time-of-Day Peaking Factors: A.M. and P.M. Peak Hours in the San Francisco Bay Area

AM/PM Peak Hour Trip Purpose	Trip Direction	1965 Survey	1981 Survey	1990 Survey	1990/2010 Forecasts
AM Peak Hour Factors					
Home-Based Work	H –> W	0.17021	0.15656	0.15436	NA
Weighted Average	W –> H	0.00462	0.00483	0.00329	NA
Home-Based Non-Work	H –> NW	0.03162	0.04146	0.05319	0.04476
	NW –> H	0.01261	0.01459	0.01549	0.01576
Non-Home-Based	NW –> NW	0.02077	0.02404	0.02797	0.02404
HBW Drive Alone	H –> W	NA	0.14597	0.14418	0.14597
	W –> H	NA	0.00514	0.00352	0.00514
HBW Shared Ride 2+	H –> W	NA	0.17763	0.18514	0.17763
	W –> H	NA	0.00172	0.00158	0.00172
PM Peak Hour Factors					
Home-Based Work	H –> W	0.00686	0.00801	0.00788	NA
Weighted Average	W –> H	0.15601	0.12637	0.12533	NA
Home-Based Non-Work	H –> NW	0.03162	0.03528	0.02769	0.03626
	NW –> H	0.05506	0.06155	0.05050	0.06325
Non-Home-Based	NW –> NW	0.08814	0.08388	0.08207	0.08388
HBW Drive Alone	H –> W	NA	0.00790	0.00837	0.00790
	W –> H	NA	0.12661	0.12612	0.12661
HBW Shared Ride 2+	H –> W	NA	0.00857	0.00661	0.00857
	W –> H	NA	0.13595	0.12066	0.13595
Bay Bridge Spread Peak Factor		NA	NA	NA	0.62000
Ala/SC Spread Peak Factor		NA	NA	NA	0.70000

Table 2: Combination of Traditional Trip Factors and Departure Choice Model, A.M. Peak Hour in the San Francisco Bay Area

Trip Purpose	Trip Direction	AM Two-Hour	AM Four-Hour	2-HR as % of 4-HR
Home-Based Work, Drive Alone	H –> W	***	0.3858	NA
	W –> H	0.0071	0.0123	57.7%
Home-Based Work, Shared Ride 2+	H –> W	***	0.4390	NA
	W –> H	0.0042	0.0073	57.5%
Home-Based Non-Work	H –> NW	0.0666	0.1154	57.7%
	NW –> H	0.0272	0.0453	60.0%
Home-Based School	H –> School	0.2840	0.3622	78.4%
	School –> H	0.0114	0.0223	51.1%
Non-Home-Based	NW –> NW	0.0568	0.1158	49.1%
Small Trucks	O –> D	0.1170	0.2480	47.2%
Medium Trucks	O –> D	0.1405	0.2885	48.7%
Large Trucks	O –> D	0.1150	0.2340	49.1%

*** Home-to-Work AM vehicle trips are derived from departure time choice model.

Table 3: Final Home-to-Work Departure Time Model,
Binomial Logit Model #18W and Model #19W

Peak Utility	Variable Name	Model #18W Coeff.	T-Stat	Model #19W Coeff.	T-Stat
▣	Constant	-0.2877	(5.8)	-0.1309	(9.5)
▣	CTFT	-0.05540	(3.0)	-0.05556	(3.0)
▣	SR Dummy	0.2946	(2.7)	0.2953	(2.7)
▣	Auto Distance	5.153E-02	(4.6)	5.254E-02	(4.7)
▣	Auto Distance^2	-8.366E-04	(3.7)	-8.464E-04	(3.8)
▣	Bridge Dummy	-0.3912	(2.0)	-0.387	(1.9)
▣	HH Income	2.861E-06	(1.9)		
▣	SFOBB WB	-0.6447	(1.8)	-0.6496	(1.8)
▣	Retail Industry	-0.3421	(2.0)	-0.3515	(2.1)
Log Likelihood		**-1391.6**		**-1393.5**	

Utility(Off-Peak) = 0
Utility(Peak) = constant + beta01 * CTFT . . . etc.

Variable Definitions:
CTFT = Congested Time Less Free-Flow Time, zone-to-zone
SR Dummy = Share Ride 2+ Dummy variable
Auto Distance = Door-to-door auto distance, in miles
Auto Distance^2 = Square of door-to-door auto distance, in miles
Bridge Dummy = Bridge crossing dummy variables (based on drive alone toll)
HH Income = Household Income in 1989 constant dollars.
SFOBB WB = Bay Bridge AM Westbound dummy variable
Retail Industry = Retail occupation, by zone of work.

Log Likelihood Ratio Test: 95% chance that Model #18W is statistically significantly better than Model #19W, 2(1393.5-1391.6) = 3.8, at 1 degrees of freedom.*

Note: In the final MTC model system application, model #19W is used.

Table 4: Regional Peak Spreading, 1990-2020 San Francisco Bay Area
Regional Home-to-Work Person Trips

Mode	Year	AM Peak Choice	%	non-AM Peak Choice	%	TOTAL
	1990	963,018	55.2%	781,961	44.8%	1,744,979
Drive	2000	1,037,018	54.8%	856,484	45.2%	1,893,502
Alone	2010	1,179,485	53.2%	1,038,745	46.8%	2,218,230
	2020	1,263,530	52.5%	1,142,330	47.5%	2,405,860
	1990	80,376	59.8%	53,956	40.2%	134,332
Shared	2000	90,600	59.2%	62,496	40.8%	153,096
Ride 2	2010	104,578	58.0%	75,761	42.0%	180,339
	2020	116,521	57.6%	85,747	42.4%	202,268
	1990	17,078	70.6%	7,097	29.4%	24,175
Shared	2000	19,200	68.9%	8,677	31.1%	27,877
Ride 3+	2010	22,770	67.0%	11,206	33.0%	33,976
	2020	25,291	66.3%	12,830	33.7%	38,121
	1990	1,060,472	55.7%	843,014	44.3%	1,903,486
	2000	1,146,818	55.3%	927,657	44.7%	2,074,475
Total	2010	1,306,833	53.7%	1,125,712	46.3%	2,432,545
	2020	1,405,342	53.1%	1,240,907	46.9%	2,646,249

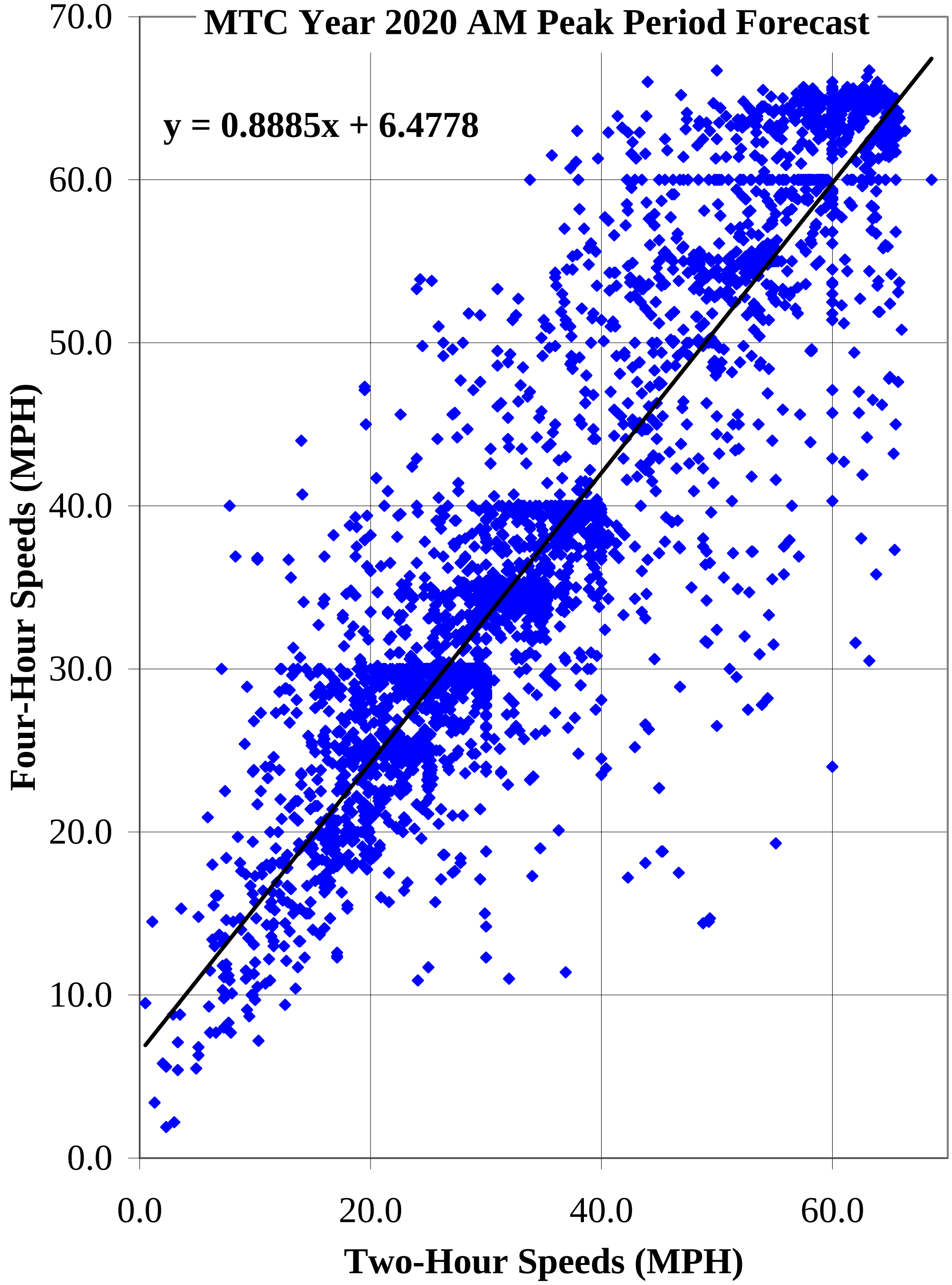
Table 5: Multinomial Departure Choice Time Models for Daily Home-to-Work Auto Person Trips

Alternative Shoulder	Alternative Peak	Variable Name	Model 20W Coeff.	Model 20W T-Stat.	Model 21W Coeff.	Model 21W T-Stat.	Model 22W Coeff.	Model 22W T-Stat.
▣		Constant	0.6003	(4.9)	0.6004	(4.9)	0.6012	(4.9)
	▣	Constant	1.372	(12.7)	1.431	(12.6)	1.613	(11.1)
▣		CTFT	-0.02677	(1.0)	-0.02698	(1.0)	-0.02817	(1.0)
	▣	CTFT	-0.07152	(2.9)	-0.07157	(2.9)	-0.07687	(3.0)
▣		SR Dummy	0.1966	(1.2)	0.1973	(1.2)	0.1977	(1.2)
	▣	SR Dummy	0.395	(2.8)	0.3952	(2.8)	0.3793	(2.7)
▣		Auto Distance	0.04524	(3.3)	0.04528	(3.3)	0.0455	(3.3)
	▣	Auto Distance	0.07538	(5.6)	0.07513	(5.6)	0.07684	(5.7)
▣		Auto Distance^2	-5.256E-04	(2.2)	-5.254E-04	(2.2)	-5.259E-04	(2.2)
	▣	Auto Distance^2	-1.101E-03	(4.3)	-1.102E-03	(4.3)	-1.119E-03	(4.3)
	▣	Bridge Dummy	-0.3862	(1.9)	-0.385	(1.9)	-0.4065	(2.0)
	▣	SFOBB WB	-0.6333	(1.8)	-0.6353	(1.8)	-0.7418	(2.0)
	▣	Retail Industry	-0.3519	(2.1)	-0.4078	(2.4)	-0.4074	(2.4)
	▣	Service Industry	- - -		-0.1594	(1.6)	-0.1601	(1.6)
	▣	Rural Job	- - -		- - -		-0.457	(1.5)
	▣	Suburban Job	- - -		- - -		-0.1848	(1.6)
	▣	Urban Job	- - -		- - -		-0.2867	(2.2)

Utility(Off-Peak) = 0
Utility(Shoulder) = constant + beta01 * CTFT . . . etc.
Utility(Peak) = constant + beta02 * CTFT . . . etc.

Variable Definitions:
CTFT = Congested Time Less Free-Flow Time, zone-to-zone
SR Dummy = Share Ride 2+ Dummy variable
Auto Distance = Door-to-door auto distance, in miles
Auto Distance^2 = Square of door-to-door auto distance, in miles
Bridge Dummy = Bridge crossing dummy variables (based on drive alone toll)
HH Income = Household Income in 1989 constant dollars.
SFOBB WB = Bay Bridge AM Westbound dummy variable
Retail Industry = Retail occupation, by zone of work.
Service Industry = Service occupation, zone of work
Rural Job = Dummy variable for job in rural area
Suburban Job = Dummy variable for job in suburban area
Urban Job = Dummy variable for job in urban area (not CBD)

Figure 1
Two-Hour vs Four-Hour Speed Scatterplot
MTC Year 2020 AM Peak Period Forecast



Short-Term Model Improvements in 4-Step Travel Models in Florida

Sunil K. Saha and Kenneth D. Kaltenbach, *The Corradino Group*;
and Shi-Chiang Li and William L. Cross, *Florida Department of Transportation*

Abstract

Florida MPOs use a 4-step modeling system in their travel models. The complexities of the models vary with the size of the area and the available travel modes. The models use a standardized procedure under the umbrella of FSUTMS. Over the last five years, the authors of this paper were involved in several studies to improve the 4-step travel models in Florida. Among them are: a life-style based trip generation model, 2-digit speed-capacity tables, highway-only models, time-of-day models, truck model, trip distribution using a purpose-specific mix of free-flow and congested skims, use of school districts in distributing public school trips, purpose-specific internal-external trips, and facility-specific volume-delay functions. Model performance has been improved significantly through the implementation of these improvements. This paper will address the improvements that have been made to several urban and regional models in Florida.

Collection of Highway Speeds Using Global Positioning Satellites (GPS)

Charles M. Baber, *Baltimore Metropolitan Council*

Abstract

The Baltimore Metropolitan Council (BMC), staff to the designated Metropolitan Planning Organization for the Baltimore region, has among its many responsibilities the monitoring of traffic conditions under the Congestion Management System (CMS). As part of this work program, traffic conditions such as traffic volumes (counts), intersection delay, queue length, traffic accidents, and average travel speeds are used as indicators of the level of service and to identify congested corridors in the region. These data are also used in the analysis of potential improvements in the corridor and the prioritization of projects within the corridor. The BMC has employed the use of GPS in the collection of vehicle speed data. With use of a standard laptop, low end GPS receiver, and a probe vehicle, staff has been able to collect average running speeds for various facility types.

The BMC staff has developed various software tools to analyze and display the collected data. This includes the conversion of output from the GPS receiver into meaningful graphs and maps depicting travel speed by time and location. Staff has also developed software that allows the averaging of several travel time samples over a given route. Methodology and other technical information were documented in June, 1998 and is available.

The staff has embarked on a major data collection effort of travel speeds within the 23 CMS corridors. This information will become the basis for a Baltimore region travel speed atlas.

EUTSTIS: A Comprehensive Database System to Support Transportation Studies in a MPO

Yanbing He, *Evansville Urban Transportation Study*

Abstract

The essential difference between a GIS and a traditional database management system (DBMS) is that GIS, in addition to attribute data, contains locational information. By this characteristic, GIS is being introduced into various facets of transportation planning, which has particularly facilitated the travel demand forecast modeling process in two significant ways: visualization and spatial analysis. However, these two functions are only taking limited roles in the entire data processing, while using GIS alone is usually ineffective to address the issues of precise data queries, huge data storage, data provision at the project level, data compatibility, end-user interface customization, and learning curve. For the middle and small transportation agencies, the constrained resources in both finance and personnel have limited their capabilities to overcome these deficiencies when applying GIS-T. Therefore, a comprehensive database system composed of traditional DBMS and GIS has been studied and applied into practice to respond the challenges, which is thoroughly discussed in this paper.

Evansville Urban Transportation Study (EUTS), the MPO in Evansville, Indiana, has recently developed a Transportation Information System (EUTSTIS) under Microsoft Access 97. The initial version of the EUTSTIS is composed of three subsystems: 1) Inventory, 2) GIS, and 3) Tool Box. All of the numerical information within the agency are stored and managed together, while many text documents and graphic objects are indexed and linked with the system through OLE. The database is designed such that: 1) data can be timely updated across the entire system; 2) operations are carried out through the Graphic User Interfaces (GUI); 3) the data storage space is minimized by multiple normalization; 4) data formats are fully compatible with MINUTP and other currently used programs; and 5) GIS functions are integrated and utilized for spatial analysis and data visualization, while other data management and processing are handled by DBMS.

The key finding is that the capabilities of keeping information updated and consistent for the travel modeling and other transportation studies can be considerably enhanced by implementing the simple and powerful DBMS technology along with GIS. The practice in EUTS has proved that a comprehensive database is a very efficient and promising solution for the middle and small sized agencies to improve the quality of services at a minimum overall cost.

A GIS-based Toolbox for the Development of Point-level Socioeconomic Data

Susan Hendricks, *KJS Associates*; Jerry Everett, *Federal Highway Administration*; and Gary Hendricks, *KJS Associates*

Abstract

The reliability of a travel demand forecasting model depends heavily on the accuracy of the data input to the model. Accurate business data, specifically the number and type of employees located at the business sites within a particular area, is difficult to obtain and the data that are available are often not very accurate. In fact, employment data is often considered the greatest source of error in a travel demand model and considerable effort may be expended in the model calibration process to analyze and compensate for inaccurate employment data. Public agencies use a variety of methods to obtain employment data for their travel demand models, but there are universal difficulties and problems associated with these methods. The two most significant problems with employment data are the time required to assemble the data, and the difficulty in validating and analyzing the data.

In a recent research effort performed for the Federal Highway Administration, the authors investigated the potential utility of data obtained from nontraditional sources and specified tools to utilize these data in travel demand forecasting models. The research focused on sources of data at the individual business level, and the specification of tools to visualize, correct and analyze these data. The research conducted in the first phase of the project identified several good sources of data available at the individual business level. Although many sources have some value that make them worth considering, alone each has some particular deficiencies, and they are more reliable when used in combination with other data. Thus, there is a need for structured tools to merge and reconcile data from several sources and to display the data geographically in a way that facilitates validation and analysis. The research project is currently in its second phase, which is the development of these tools.

The paper will present the results of the research effort, including a description of the data available and the specification of the tools being developed. In addition, the presentation will include a prototype demonstration of these software tools.

Panel Survey Incorporating Customer Attitudinal and Travel Data: Methodological Issues and Applications to Transit Policy and Planning

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Abstract

A wide variety of transit service, fare and policy issues require information on consumer travel behavior, customer opinions or both. To meet these needs, New York City Transit initiated its "Transportation Panel" study, involving a cross-section of 1,500 New York City residents. The Panel Study combines a telephone survey concerning customer attitudes on bus and subway service with collection of detailed travel data using a self-administered two-day trip diary. As the Panel Study nears completion of its fourth year, a rich base of experience has been compiled which will be of broad interest.

This paper reports on a range of key methodological aspects of the study, include response and retention rates; use of incentives; effect of increasing the frequency of respondent participation; validation of travel data with actual ridership levels, and effects on attitudes and travel behavior of the "aging" of respondents through successive waves of interviewing.

The paper also demonstrates the effective uses of the results for transit agency planning and monitoring. These include analyses of travel behavior, evaluation of the impacts of major changes in fare policy, tracking of customer opinions, and assessments of transit's competitive position. Major conclusions are that the Panel approach is highly valuable for tracking customer opinion, particularly in showing the impact of policy changes, obtaining times results on issues as they approach a decision, and providing a richly detailed database of trip information. More difficult has been tracking changes in transit's share of overall travel and relating attitudinal ratings with mode choice.

Introduction

In its continuing efforts to monitor the travel behavior and attitudes of its customers and potential customers, MTA New York City Transit established a Transportation Panel in 1995. The panel is drawn from NYC (which represents approximately 90% of the bus and subway ridership) and is currently a cross-section 1500 adult residents who are interviewed every three months (500 per month).

Until the beginning of this year, a combination of a diary and telephone interview was used to obtain an individual's travel behavior for a pre-determined two-day period as well attitudes toward various transportation modes including bus, subway, taxi, and automobile. Walking is considered a form of transportation if it's for more than 10 minutes at a time.

Most survey questions remain the same from quarter to quarter with some inserted or dropped depending on relevance at that time. The attitudinal information includes specific attributes (typically measured on a 0 to 10 scale, with 10 being the highest) for each mode as well as overall satisfaction. Since January 1, 1999, all information has been obtained through the telephone interview with travel behavior covering the previous two days; a preliminary assessment shows greater efficiency in data collection and an indication of greater accuracy since the time between the travel period and interviewing is reduced. Research is conducted in several languages including English, Spanish, Korean, Russian, and Chinese (Cantonese and Mandarin).

This paper presents an analysis of key measures to assess the validity of the panel approach to obtaining attitudinal and travel behavior information; diary and telephone data up through the third quarter of 1998 are used. In addition, a model analyzing the drivers of customer satisfaction with the New York City subway system is postulated and tested. Conclusions as well as implications for the future are drawn.

Methodological Issues

Effective use of the Transportation Panel first requires understanding the methodological strengths and limitations of the survey. Evaluation of methodological issues has shown how to maximize the Panel's usefulness for program and budget analysis.

Response rates/Attrition

The first key methodological issue is response rates. In New York City as across the country, fewer and fewer people are willing to participate in telephone interviews. In the context of the panel methodology, several response rates are important:

- Screened and qualified: Potential respondents' first contact with the panel project is the recruitment interview. A large number of contacted households are lost at this point, primarily due to refusals at the start of or during the interview. Overall, 23 percent of persons contacted on the phone complete the short recruitment interview and qualify to be panel members. This is comparable with the 21 percent of contacts who complete a much longer tracking survey.

- Agree to participate: Those passing the screener are then asked to participate in the panel. Somewhat over one-half agree, or a total of 14 percent of those initially contacted.

- Complete initial wave: New panel members were sent a diary to complete and mail back (prior to switchover to 48-hour telephone recall) and then called for a follow-up telephone interview. Just over one-half of recruited participants complete this first wave of interviewing, or 8 percent of those initially contacted.

- Retention after first wave: Unlike one-time surveys, panel participants are asked to complete additional waves of interviewing once per quarter. This introduces a final source of attrition. Table 1 shows that over successive waves, the retention rate rises to about 75 percent of those interviewed in the prior wave. The cumulative effects of attrition, however, mean that by the seventh or eighth wave, only about 10 percent of those completing the first wave are still active panelists.

Validating trip rates

Data validation concerns whether results from the survey truly reflect the behavior and opinions of the New York City adult population. With respect to travel behavior, panel results can be compared with actual ridership on bus, subway and taxis to determine data validity. Table 2 compares trip rates for each mode. For comparison purposes, results from the 1995 National Personal Transportation Survey (NPTS) are also shown. Survey results for auto trips are included although the actual number of auto trips is unknown.

Validation results are mixed. The Transportation Panel appears to overstate both bus and subway trips while understating taxi trips. NPTS comes reasonably close to the actual number of subway and taxi trips (although given subway ridership growth between 1995 and 1998, NPTS actually overstates subway trips). But NPTS overstates bus trips even more than the panel does. Also notable is the large difference in estimated auto trips.

There are two potential reasons to explain the errors in trip rates: (a) sample bias (if the sample does not represent the New York City adult population); and (b) misreporting of respondents' actual trip-making. Sample bias might seem likely given the volume of refusals and attrition observed above; however, comparison between panel respondents and Census data on demographic characteristics such as age, income, race and ethnicity reveal no differences that would explain discrepancies between actual trip rates and survey results. Based on data analysis and interviews conducted with selected panel respondents to investigate this issue, two explanations seem most likely:

- Self-selection for transit-oriented persons. Transportation issues are of inherently greater interest to New Yorkers who use public transportation than those who primarily use the auto and/or taxi. Effort is made to avoid creating a bias from this—respondents are not told the identity of the study sponsor and questions about autos and taxis are included in the survey. Nevertheless, it appears that transit users are probably overrepresented in the sample.

- Respondent desire to report activity. In-person interviews reveal that panel participants tend to be people who like to be helpful and relevant to the study purposes. It appears that in this spirit, some respondents report travel for days they did travel instead of the diary-appointed days that they did not travel. In addition, respondents may report trips they typically make even if they happened not to make the trip on the diary-appointed day.

The overreporting of transit trips is a significant issue and a major reason that in 1999 NYC Transit began to collect trip information using 48-hour telephone recall.

Validating attitudinal results

It is also important to assess whether panel interviewing produces an accurate picture of New Yorkers' views of transportation services. Are results consistent with other surveys? Does repeated interviewing affect respondent opinions, perhaps through some type of sensitizing process?

Results on these issues are quite positive. First, panelists' opinions are consistent with those found from other surveys. The trendline for ratings of subway and bus are similar to those from separate telephone surveys conducted with fresh respondents each time, although the ratings themselves are somewhat higher in the panel.

Second, repeated interviewing does not affect the results. Figure 1 shows that ratings (both the rating itself and the trendlines) are the same for panelists interviewed only once or twice before attriting as for panelists interviewed more times.

These positive results can be attributed to two causes. First, views on transportation services are widely shared in the New York City population and vary little by demographic characteristics, geography or modes or specific transit lines used. Given this relative homogeneity, there would have to be dramatic shifts in the sample composition to generate noticeable problems in results.

Second, traveler views are based primarily on first-hand experiences moving around the city. Perceptions are shaped by daily experience; the influence of 15 to 20 minutes of interview questions every three months pales in comparison.

Fare Policy Applications

This section presents highlights from several applications of the panel research to fare policy changes undertaken by NYC Transit.

Fare policy and customer satisfaction

NYC Transit introduced three major changes in fare policy in 1997 and 1998: free transfers between bus and subway, introduced in July 1997; an 11 for 10 discount program in January 1998; and transit passes in July 1998. These initiatives came after a 20 percent fare increase in November 1994.

Panel data show the impact of these fare changes on customers' satisfaction with transit service. As shown in Figure 2, customers' ratings of "value for the money" for subway and bus service fell as a result of the fare increase and rebounded to an unprecedented level with the fare policy initiatives. Of the three initiatives, free transfers produced the biggest impact on "value for the money" ratings, for three reasons: they were introduced first; they represented a steep 50 percent discount in the fare for trips involving bus and subway transfers; and beyond the monetary savings they gave consumers the value of greater flexibility and convenience.

Figure 2 also shows that the fare changes similarly affected customers' overall ratings, though more modestly.

Purchase intent

Another use of the panel is to help assess customer reception to possible new products. Panelists were asked in the spring of 1998, for example, about the likelihood that they would purchase 30-day and 7-day Unlimited Ride passes when they became available in July 1998. As with any consumer "intent to buy" questions, it is known that more respondents will anticipate buying a new product than will actually do so. The longitudinal character of the panel offers an opportunity to quantify appropriate discount factors. Table 3 shows the results. Of those who said they were “very likely” to buy a 30-day pass, 30 percent bought one of the passes in their most-recent purchase in the third quarter of 1998. Likewise, passes were bought by 21 percent of those initially saying they were very likely to buy a 7-day pass, by one in six of those “somewhat likely” to buy and one in eleven of those “somewhat unlikely” to buy a pass.

These discount factors can be used to inform analyses of likely customer response to future fare changes.

Characteristics of ridership growth

With the fare initiatives spurring growth in subway and bus ridership, it was important to understand the sources of growth. Were these new riders attracted to transit from the auto or taxi? Was ridership growth entirely from persons buying Unlimited Ride passes or did customers buying tokens or the traditional MetroCard account for some of the increased patronage?

A method was developed to isolate incremental ridership growth from the normal churn that occurs as moves, job changes, new living situations, gain or loss of income and other factors prompt people to alter their transportation habits. The method uses a simple question: Is the respondent riding each mode more, less or about the same as a year ago? The proportion of respondents riding more generally rises when actual ridership grows. For example, 26 percent of respondents interviewed in 3Q98 said that they were riding the subway more than a year earlier compared with 23 percent of those interviewed in 2Q98, reflecting an increase in ridership.

Table 4 shows that the ridership increase was concentrated among pass buyers. Using the longitudinal aspect of the panel, the table shows 2Q98 and 3Q98 responses to the “riding more” question for customers buying passes and other fare media in the third quarter. Among pass buyers, 49 percent were “riding more” as of the third quarter, far above the 29 percent of the same respondents in the second quarter. By contrast, there was no significant change in “riding more” responses among subway customers buying tokens or the traditional pay-per-ride MetroCard.

Modeling Customer Satisfaction Using Transportation Panel Data

One purpose of the Transportation Panel is to identify and understand key drivers of customer satisfaction. The tracking of specific attributes is helpful in monitoring customer opinions and it also facilitates the use of complex analytic methods to better understand why customer ratings vary.

Traditional analytic models

Most models of customer satisfaction have been bi-variate analyses in which pairs of variables are studied, or more traditional regression models in which several variables are assumed to have a direct impact on the outcome. With these approaches, one or more independent variables are analyzed with respect to the dependent variable of customer satisfaction. Examples of such bi-variate and multiple regression models are shown in Figures 3 and 4, respectively.

The positive aspects of using a bi-variate approach are that it's relatively easy to implement and conceptualize and that some insight into the magnitude of existing relationships is possible. There are significant weaknesses, however, including the likelihood of postulating an overly simplistic or even erroneous view of causality. Most real-world situations have several factors acting at once and the simultaneous impact of multiple variables is not incorporated in a bi-variate model.

Multiple regression analysis can overcome weaknesses of the bi-variate approach since several variables may be considered at once. This is an improvement, but in the intricate world of customer attitudes and satisfaction, greater complexity is often needed.

Structural equation modeling

Structural equation modeling affords the opportunity to allow selected variables to be both dependent in nature (i.e., the outcome of other factors) and, in turn, independent so that it can influence one or more others. Thus, a network of variables can be postulated that is more closely aligned with the complex interrelated structure of customer attitudes and satisfaction. An example of a path, or structural, model is shown in Figure 5; variable D is one that is both dependent and independent in nature.

It is important to note that such models need to be pre-specified and then tested with appropriate data. This is a rigorous inspection, one that will determine if the data support the theory.

A Customer Satisfaction Model for MTA New York City Transit

Analysis of prior research has helped in postulating one possible model of customer satisfaction. Using data from the Transportation Panel, a proposed model is presented in Figure 6. The boxes represent 11 of the attributes that participants in the panel are asked to rate. The straight and curved arrows depict different types of relationships (causal and non-causal) that are believed to exist and are explained on the next page.

Definitions of the model variables

Panel members rate the following variables from the Transportation Panel on a 0 to 10 scale on a quarterly basis:

Safety: The feeling of safety from train accidents

Courtesy: Courtesy of employees, e.g., station agents who sell MetroCard & tokens; conductors

Crowding: Crowding in the subway system

Panhandlers: Absence of panhandlers (i.e., people asking for money)

Frequency: Frequency of trains arriving at the stations

Predictability: Predictability of the trains arriving at the stations

Comfort: Overall comfort in the system

Security: Sense of personal security

Speed: Speed of the customer's trip

Value: Perceived value for the money

Overall: Overall satisfaction with the subway system

Correlations among exogenous variables

The five exogenous variables (i.e., those that have no prior causal factors) are depicted in Figure 6 with curved arrows between them. This reflects the hypothesis of no prior causation -- and also the real world that non-zero correlations will exist among them (correlation but not causality!). As a result, each will have a parameter estimate, analogous to a correlation coefficient, generated as part of the model's output.

Proposed causal paths in the NYCT customer satisfaction model

Variables in figure 6 that have straight arrows emanating from them are postulated to have links that lead either directly to the final dependent measure (i.e., customer satisfaction) or indirectly to satisfaction by first affecting others. It is possible a variable (e.g., safety) will have a direct as well as an indirect influence. Each causal link in the model will have its own estimated coefficient.

The following direct causal relationships in the customer satisfaction model are hypothesized to exist:

Safety to Value: Safety from train accidents affects the perceived value of the ride

Courtesy to Comfort: Employee courtesy affects the sense of comfort within the system

Crowding to Comfort: Crowding influences the sense of comfort

Panhandlers to Security: Panhandling affects a customer's sense of personal security

Frequency to Security: Frequency of train arrival affects perceived personal security by its impact on the amount of time a customer spends on the train platform

Frequency to Speed: Frequency of train arrivals affects the overall time of the customer's trip

Predictability to Speed: Predictability of train arrivals affects the customer's perceived speed of the overall trip

Security to Comfort: Sense of personal security affects one's comfort within the system

Comfort to Value: Comfort influences perceived value for the money (i.e., fare)

Speed to Value: Speed of the overall trip affects perceived value for the money

Comfort to Overall: Comfort affects overall satisfaction with the subway

Security to Overall: Personal security affects overall satisfaction

Speed to Overall: Speed of the trip influences overall satisfaction

Value to Overall: Perceived value for the money influences overall satisfaction

Preliminary results

A review of the initial output shows that all hypothesized causal links in the model are significant at the 95% confidence level; as a result, they are being retained in the final model. Diagnostics reveal some "stress" exists in the overall model through the imposition of constraints (i.e., no paths between certain pairs of variables); the one constraint that appears to be significant is from safety to comfort. Upon reflection, there is logic to the notion that one's perception of an environment free from (or fraught with) train accidents will affect that person's comfort level; thus, a path from safety to comfort is established for the final model. Other potential paths that would alleviate stress in the model are not included for lack of strong theoretical underpinnings.

The initial overall model explains 98% of the variance in the dataset, a high percentage for a non-saturated model (one that has a complete set of paths). This is an indication that this dataset supports the hypothesized model of customer satisfaction.

Final model

The final model is the same as the initial one with the addition of the one path from safety to comfort. With the re-estimation of all parameters, each path is significant with 95% confidence. Figure 6 depicts this model and includes the standardized beta weight for each path. Each circle represents the error term for an endogenous variable (one with a prior causal influence) and reflects that the variable is not estimated perfectly.

This model explains over 98% of the variance in the 3Q 1999 dataset. As a check, the entire network of variables has been tested using data from 4Q1999. These hypothesized paths are again significant, an indication of stability, and a similar amount of variance is explained.

Some variables have a greater impact than do others in the model. This is to be expected and allows us to compare the relative impact of factors that help determine customer satisfaction. While this model may currently be valid for the New York subway system, it may not for other systems in the country or around the world. The same analytic techniques, however, can still be employed.

The structural equation approach to customer satisfaction modeling may also be used within the same system at different points in time to see if the relative strength of causal factors is changing. This is important because the model can be used to work with staff and operating departments when assessing the cost-benefit of various improvements in the system. By associating expenses with enhancing a causal factor (e.g., improving courtesy, reducing crowding), we can then estimate the cost to increase customer satisfaction from its current level to another given point. This approach may also be used in forecasting the cost of improvements to achieve particular ridership levels.

Implications for the future

Several modifications can be incorporated and tested to expand the usefulness of modeling customer satisfaction. These include, but are not limited to:

- Incorporating customers' mode choice at the individual level and the amount they travel

- Developing more complex but applicable models to assess drivers of customer satisfaction and travel choice; e.g., include other measures of environment such as subway station and car

- Evaluating the cost and impact of modifying key drivers to achieve higher levels of satisfaction and ridership

Conclusions

NYC Transit's experience with the Transportation Panel shows:

- It is difficult to accurately measure the number of trips taken by mode using mail-back diaries; telephone interviews, especially with 24 and 48-hour recall of travel, show promise

- The panel method of surveying can track customer attitudes effectively

- Modeling can provide an increased understanding of the drivers of customer satisfaction

- Customer surveys in conjunction with modeling can enhance the effectiveness of the decision-making processes that affect customer satisfaction and choice of ridership

Table 1: Attrition Rates with Successive Waves of Interviewing

Wave	Retention from previous wave	Retention from first wave
1	100%	100%
2	58%	58%
3	61%	35%
4	76%	27%
5	74%	20%
6	74%	15%
7	80%	12%
8	79%	9%
9	67%	6%

NYC Transit Transportation Panel, 1Q95 through 2Q98.

Table 2: Trip Rates from Transportation Panel Compared with Actual and NPTS.

	Mode			
	Subway	Bus	Taxi*	Auto
	Number of trips per person per day			
Actual	.47	.23	.13	n.a.
NYCT Panel	.64	.39	.07	.71
NPTS	.48	.44	.11	1.19

Actual subway and bus ridership is for March-May 1998; taxi ridership is estimated for 1998.

NYC Transit Panel data are for January-July 1998.

National Personal Transportation Survey (NPTS) data are for 1995. Source: computer tabulations supplied by New York State Department of Transportation.

* Taxi includes medallion cabs and for-hire vehicles.

Trip segments in multi-leg trips are counted separately.

Table 3. Likelihood to Buy Unlimited Ride Passes in 2Q98 vs. Actual Purchase Behavior in 3Q98

	Likelihood to Buy Passes, 2Q98			
	Very likely	Somewhat likely	Somewhat unlikely	Not at all likely
	Percent Buying Pass, 3Q98			
30-day Unlimited Ride pass	30.1%	15.8%	7.6%	3.5%
7-day Unlimited Ride pass	20.9%	16.5%	8.8%	2.2%

Table 4. If "Riding Subway More" by Fare Media Purchased in 3Q98

	Purchased in 3Q98		
	Unlimited Ride Pass	Pay-per-Ride MetroCard	Tokens
	Percent "riding subway more than year ago"		
2Q98	29%	27%	16%
3Q98	49%	27%	17%

Figure 1. Subway Service Ratings by Number of Waves of Interviews

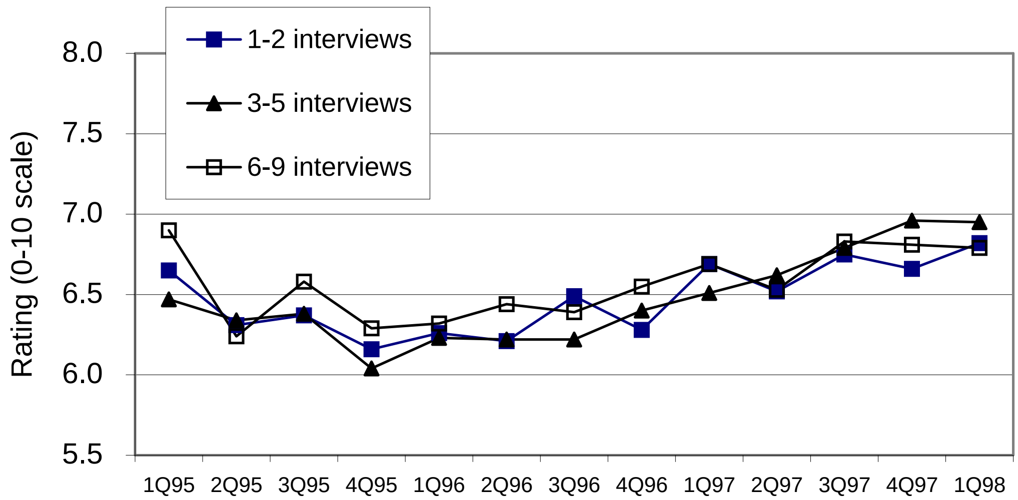


Figure 2. Customer Satisfaction Ratings and Fare Policy

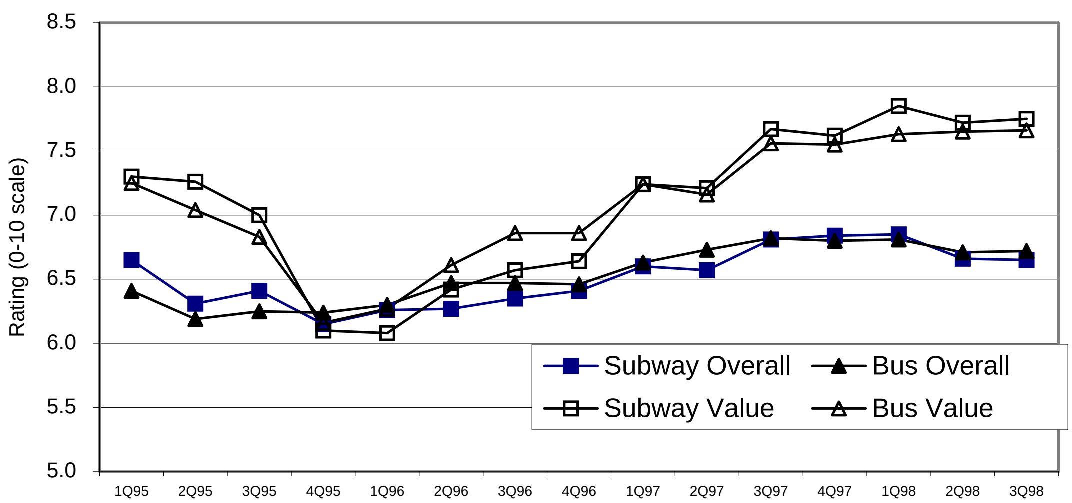


Figure 3: Hypothetical Bi-variate Model of Customer Satisfaction

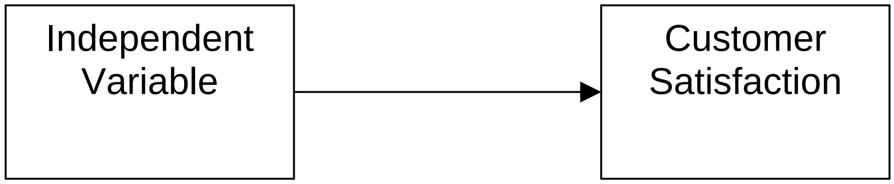


Figure 4: Hypothetical Multiple Regression Model of Customer Satisfaction

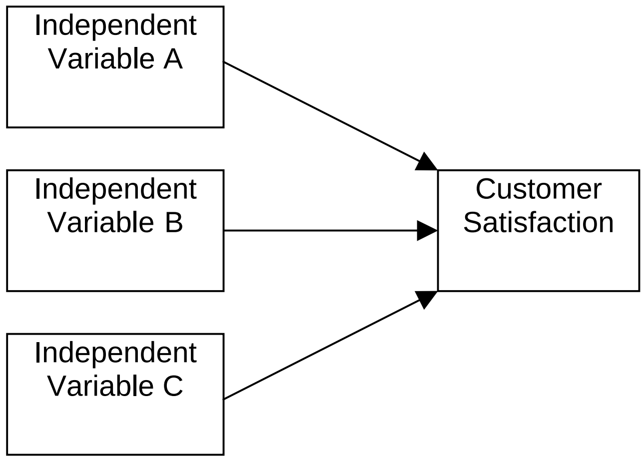


Figure 5: Hypothetical Structural Equation Model

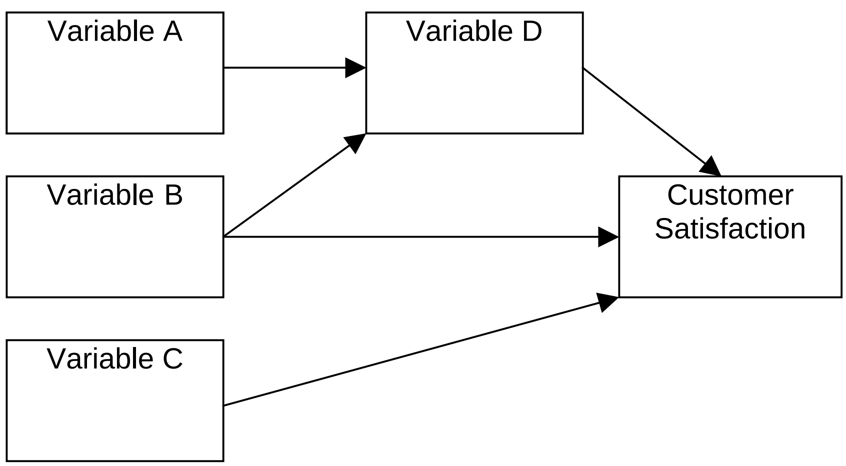


Figure 6. Proposed Customer Satisfaction Model

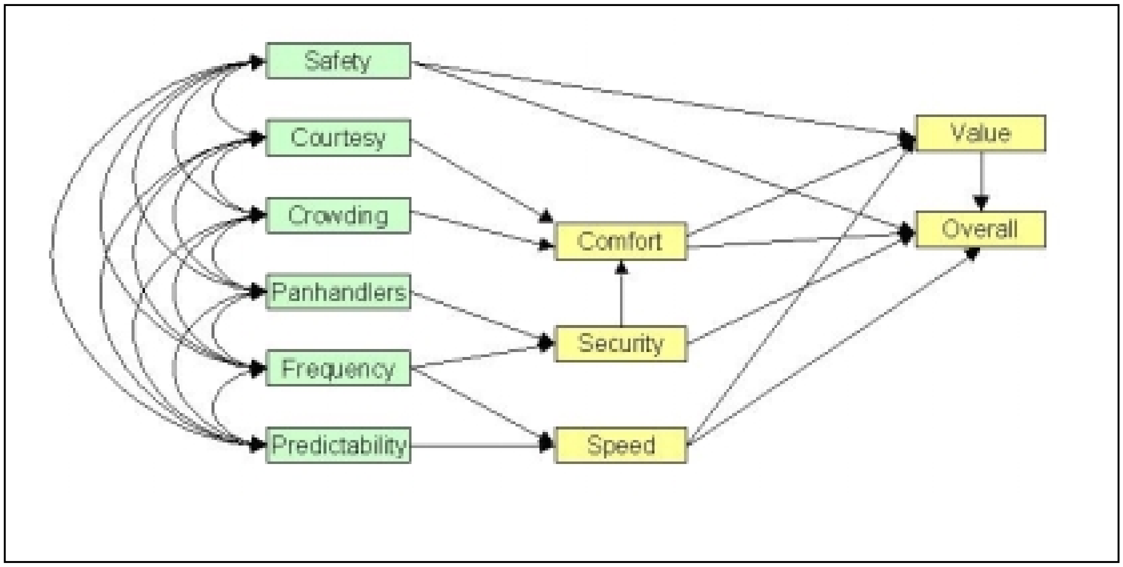
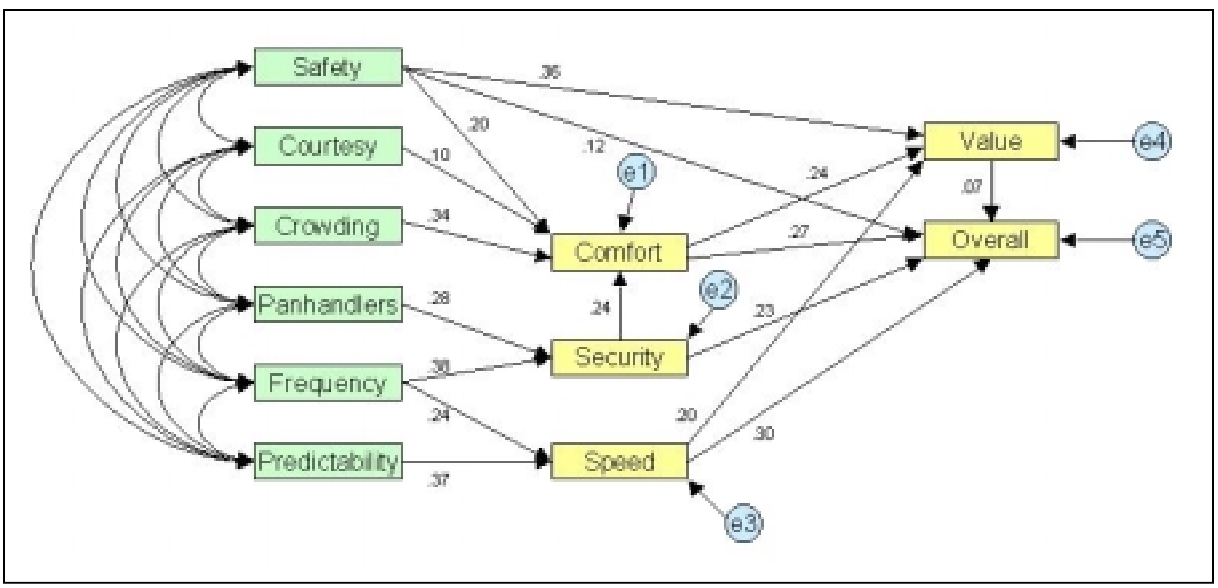


Figure 7. Customer Satisfaction Model for MTA New York City Transit



Evaluating Two-way Streets for Downtown Circulation

Timothy Boesch and Bruce Hyman, *Wilbur Smith Associates*

Abstract

The City of Providence has a traditional tightly spaced, one-way street system typical in older cities of New England complete with an overlaid highway system and connecting interchanges. Congested areas are related to the funneling of freeway traffic into intersections connecting to the highway interchanges. The study purpose was to analyze possible changes in the street system to reduce congestion at key points by changing certain streets from one-way to two-way, relocating primary bus transfer points, making dedicated bus lanes, etc. These analyses were made taking into account future traffic growth, future committed developments, and future committed intersection changes. The CORSIM micro-simulation package was selected for use in this project because of its analytical and graphical/simulation capabilities.

Data was collected as input to the project-wide CORSIM® simulation model. Data included street lengths and intersection locations, intersection configurations, turning movement volumes and percentages, cordon traffic counts, internal traffic counts, signal timings, parking locations, etc. The initial project network was built using the graphical features of SYNCHRO® for link and node input based on an existing CADD background of the study area. This SYNCHRO® file was then exported to CORSIM® format, and other information was added or changed to complete the base network. This base network was also converted into a QRSII® model which gave the modeling process an assignment function to estimate alternative scenario network responses. Using primary parking facility counts, cordon counts, turning movements and freeway counts, a proportional trip table was developed, assigned, and calibrated using QRSII® to simulate existing conditions. Thus a functioning, existing conditions base was developed in both QRSII® and CORSIM®.

For each of five alternative scenarios, additional QRSII® assignments and CORSIM® simulations were made. QRSII® assignment turning movements under each scenario were extracted and compared to the base QRSII® existing conditions assignment. Based on this comparison, appropriate changes were made to existing CORSIM® turning movement percentages and input to each CORSIM® simulation. Signal timings, entering traffic volumes, bus routes, and other factors were adjusted to get an appropriate CORSIM® simulation. The overall impacts on vehicle miles traveled, vehicle hours of travel, speeds, and other measures of effectiveness were evaluated for the entire area. For specific problem intersections, separate measures of effectiveness were evaluated.

The study has shown using a SYNCHRO - CORSIM - QRSII multiple model approach is effective. However, certain aspects of CORSIM®, such as structure type differences for freeways vs. arterial roadways, total node and link capacity, and limited diagnostic tools can complicate the process. In using QRSII® for traffic assignment, care should be taken to note actual slow down and delay locations which may need to be accounted for in the assignment process.

Development of Representative Day Scenarios to Capture the Impacts of Variation in Conditions in Transportation and ITS Planning

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Abstract

Traffic and transportation analyses based upon average, or recurrent, conditions do not account for many of the benefits of ITS services and systems. ITS services for the most part are aimed at providing a response to changing conditions. This can take the form of adjusting either traffic or transit operations, providing up to date information to system operators and the public, or responding to events. This presentation describes the use of ITS generated and other data to develop “representative day scenarios” for transportation system analysis. This work was carried out as part of a Seattle area case study investigating how to incorporate ITS into Major Investment Study (MIS) analyses.

Typically, forecasting processes are executed for expected, or average, conditions for the horizon year and consequently represent recurrent conditions and congestion. The representative day scenarios expand the analysis to account for non-recurrent situations where the transportation system may perform very differently, leading to shifts in traveler’s desired travel choices and in the impacts of the alternatives. This is especially important if ITS and other operational strategies that help the transportation system and traveler respond to changing congestion and bottlenecks due to accidents, inclement weather, construction, and other events; shifts in demand due to special events or simply normal variation; and additional information.

Statistical analysis on Seattle area peak period data (both AM and PM) from 1994 and 1995 was used to define the scenarios. The scenarios are developed around several dimensions, including event versus non-event, weather, major incidents, variations in demand (volumes), and the number of accidents. An “Event” period is defined as one that has: at least one poor weather condition (visibility, rain, wet surface, freezing rain, frozen ground, and snow cover); has lane minutes of delay greater than 30 minutes in the incident file; or has number of accidents greater than 6 in the Seattle accidents file. Non-event periods have minor fluctuations in the system’s performance and are more common. In the case study 54% of the peak periods are classified as non-event and 46% as event.

The representative day scenarios were used in simulation analyses for the Seattle area case study. The results show that capturing the impacts of variation does make a difference in the analysis of ITS. Benefits of ITS are most noticeable in under extreme conditions of incidents and inclement weather. These cases must, however, must be weighted by their probability of occurrence which the representative day scenario analysis provides. The presentation will focus on the issues associated with developing the representative day scenarios and their representation in the simulation system. It will also provide results from the Seattle Case study and show how the use of the representative day scenarios allows the observed daily variation in demand and travel times to be captured.

Evaluation of Selected Software for Analysis of Isolated Signalized Intersection

Anil K. Chagari, Central Transportation Planning Staff

Abstract

This paper provides an evaluation of the computer software models for traffic operations analyses of isolated signalized intersections based on the methodology of the 1994 Highway Capacity Manual(HCM). A number of computer software packages currently exist for traffic operations analyses of isolated signalized intersections. These software models were developed to automate the complex procedures and calculations involved in this type of analysis. For the purpose of this paper the latest versions of the following software were choosen: (1) HCS, (2) SIG/CINEMA, (3) SIDRA, (4) WCINCH94, (5) SIGNAL 94. All selected software here comply with the 1994 HCM methodology.

An existing conditions analysis was performed using program-defined default values. The results from this analysis are used as a base for comparing the output results to alternatives analyses. The purpose of design analysis is to determine the optimal splits which can improve the performance of the intersection over existing conditions. The optimization analysis is performed to determine the best cycle length, splits and phase sequence at a given time period. Some programs examine all possible combination of phase sequences to determine the optimal phase sequence, while others optimize only user-defined phase sequences. Also, it should be noted that the selected models in this study follow their own logical optimization procedures in reaching the optimal solution. Finally a sensitivity analysis is performed. The objective is to check the sensitivity of the parameters such as splits, cycle length, and phase sequence resulting from the optimization process. The HCS program which is most widely used and accepted, was selected to perform the above stated objective. The optimized variable parameters from each of these software (SIDRA, SIG/CINEMA, WCINCH94) are used as inputs to HCS. The new output performance measures from HCS (delay and LOS) were compared to the actual HCS results.

The results of the analysis indicate that all the evaluated software proved to be useful analytical tools, but they seldom provided a complete result. Each program has its own strengths and weaknesses. Even though all the programs are based on the HCM methodology, there are differences in the resulting values of MOEs from each model. The reason for this is that each model has a different optimization methodology, and the variety of input data accepted. Finally, the results of the analyses are summarized and presented in Tables. The results presented in this paper could be used in selecting appropriate software program for the analysis of isolated signalized intersections. In turn, this would provide a good overview of the program features, capabilities of the selected software and HCM methodology for evaluating isolated signalized intersections.

Path-Based Intersection Turning Movement Projections

Brian Fowler, P.E., *Vanasse Hangen Brustlin, Inc.*; and
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Abstract

The estimation of future peak-hour intersection turning movements is often the cornerstone of the process for developing the geometric design needs of a new roadway or roadway expansion project. Operational analysis of these forecasted volumes leads to the determination of laneage needs and other geometric elements. In essence, millions of roadway construction dollars can be spent well, or poorly, depending on the reasonableness of these figures.

The Florida Department of Transportation (FDOT), District 4, initiated an effort to improve “design traffic” forecasting procedures, a key portion of which was to improve procedures for developing intersection turning movements. A critical finding was that all of the documented methodologies that were investigated had a common trait. While all of the models provided a mathematical approach of getting from existing to future peak-hour turning movement projections, a “logical” relationship between the models and what happens in the real world was generally not found. All of the models investigated tended to often produce resultant projections that did not seem to correlate well with the patterns of the existing turning movements. A final method that was investigated had been developed by one of the authors. In this method, two key differences were that projected peak-hour turns were not estimated by applying an iterative “growing” procedure to the existing turns, nor was there an attempt to “force” projected turns which matched some predetermined intersection leg volumes. The methodology had a stronger tie to what actually happens; intersection turning movements are not a function of the volumes of the adjacent links. Rather, the volumes of the adjacent links are a function of the traffic which flows along each path through the intersection. This methodology considers the characteristics of each path (a complementary pair of turning movements) through the intersection critical to estimating future peak-hour turns. This method was judged to be superior in developing reasonable, “logical” estimates of future peak-hour turning movements.

Introduction

Design traffic forecasting. What is it? Why is it important? Who uses it and for what? Design traffic forecasting is the estimation of future traffic volumes. Unlike many other aspects of engineering, it is rarely “black and white.” In fact, the development of good design traffic projections is often as much art as science. The forecasting of design traffic is important because decisions about number of lanes, pavement design, bridge loading, required land purchases, are all based to some degree on design traffic. It is also used to estimate the future social and environmental impacts of a project (i.e., noise and air pollution). Design traffic projections are used by state Departments of Transportation, Metropolitan Planning

Organizations, Expressway Authorities, Turnpike Authorities, the Federal Highway Administration, the Environmental Protection Agency, Cities, Counties, and others.

In 1994, the Florida Department of Transportation (FDOT) identified the need to improve the quality, consistency, and timeliness of design traffic and 18-KIP Equivalent Single Axle Loading (ESAL) reports. As a result, an effort was initiated by the FDOT to improve both the methods and processes used to develop design traffic forecasts.

The effort was broken into the following sub-tasks:
- Methods Improvement (turn movements)
- Methods Improvement (other)
- Process Improvement
- Design Traffic Engine (DTE)
- Integrated Design Traffic System (IDTS)

Turn movement projections were quickly identified as a key component in the development of design traffic projections. The methods that had historically been employed to project turning movements had often led to projections that seemed intuitively illogical or unreasonable, for various reasons. Consider some of the potential implications of poorly estimated design turning movements. Over or under design of intersection geometry, such as number of turning lanes and storage lengths. Money wasted, or perhaps worse, lost opportunities. Insufficient designs are often uncorrectable at a later date due to untenable increases in right-of-way cost. Consider the impacts of an inappropriate design of an interchange, and the difficulties of rebuilding. In short, the impacts can be tremendously harmful.

As a result, the development of improved turn movement forecasting methods was broken out into a separate effort. Several methods of developing turning movement projections were tested; including one previously developed by Mr. Brian Fowler. Through testing of the various methods and the input of several members of the technical team, the approach proposed by Mr. Fowler was ultimately chosen for implementation. This paper discusses the results of this effort.

Path-Based Intersection Turning Movements Process

Although a variety of methods are undoubtedly used amongst transportation planning professionals, there are generally some common traits. The first is that existing turning movement counts (usually for a "peak" hour, which we will assume for simplicity throughout the remainder of this discussion) serve as a foundation. Most commonly, the second most important input is estimated future directional link volumes (generally derived from daily volumes) for the peak hour, on each leg of the intersection. The estimation of directional peak hour traffic on a link is commonplace, based on a daily volume, a directional distribution ("D") factor and a peak-hour percentage ("K") factor. With this information as input data, some mathematical procedure is then applied to obtain an output set of turning movements that coincide as closely as possible with the input directional link volumes.

It has long been accepted that a reasonable way of predicting future directional peak-hour volumes on a roadway link is to multiply estimated future daily volumes by D and K factors obtained from existing data. The assumption is that these characteristics would remain consistent over time, perhaps a reasonable assumption in most instances (although it could be argued that, particularly where traffic volumes are expected to change substantially, these characteristics could also change significantly). What is important to recognize about traffic volumes on a roadway link is that they are actually the accumulation of traffic volumes following many different trip paths (from origin to destination). Similarly, the characteristics (K and D) on a link are an accumulation of the characteristics of the traffic on each path. The total is the result of the smaller pieces. The characteristics of some paths using the same link may actually vary substantially from each other. Because the link characteristics are essentially a weighted average of the characteristics of each path, if the volumes using some paths change substantially more than others, the resulting link characteristics could change.

Similar to a roadway link, a K and D characteristic can be calculated for each "path" through an intersection. (Each intersection "path" is defined as a complementary pair of movements. At a typical four-legged intersection, there are six paths through the intersection, as illustrated in Figure 1.) In theory, a K and D characteristic could also be calculated for every individual trip path. Also similar to a roadway link, the volumes and characteristics of each "path" through an intersection are actually the accumulation of the volumes and characteristics of many paths. The same thoughts regarding the transferability of link traffic characteristics to future conditions can be applied to intersection path characteristics (and indeed individual trip paths).

There is a completely dependent relationship between intersection volumes and the volumes on the adjacent links. What goes in must come out, and the intersection volumes must match both ins and outs. The question could be asked, "which is dependent on which?" The assertion from the "common" methods discussed previously is that the intersection volumes are dependent on the adjacent link volumes (turns are adjusted in an attempt to match "input" link volumes). It is more logical that link volumes are a result of the turning volumes at adjacent intersections, as illustrated in Figure 2. (In reality, both are a result of the complete set of trip paths that use the link or the intersection path. The paths that use the link are an accumulation of the smaller sets of paths using the intersection.) In fact, there is one major problem with the assumption that an estimated set of adjacent link volumes would "drive" intersection turning movements. When adjacent peak-hour link volumes are independently estimated, the "ins" to the intersection generally will not match the "outs". Hence, even at the outset, methods designed to force intersection turns to match input link volumes "struggle" to make that match, since in fact they never can.

Thought of another way, both link and intersection path characteristics are a result of the combination of a set of smaller pieces (individual trip paths). Perhaps ideally we would estimate the trips on each individual trip path. But in terms of "hierarchy", the trip paths using a link can be subdivided into unique subsets of paths that use each of the adjacent intersection paths. Again then, it seems more logical to say that what happens on a link depends on what happens at the adjacent intersection.

This thought process led to the "revelation" that peak-hour link volumes or characteristics should not be an *input* into the intersection turning movement forecasting process. Rather, they should be an *output* from the process. In the same way that K and D factors are applied to daily link volumes, they can be applied to daily volumes along an intersection path. If intersection turning volumes are estimated using this approach, the peak-hour volumes and K and D characteristics on the adjacent links are outcomes. The resulting K and D characteristics on the adjacent links are weighted averages (by future intersection path volumes) of the K and D characteristics of the contributing intersection paths. The K and D on the links are now responsive to changes in the relative influence of contributing paths.

To calculate K and D characteristics for intersection turning paths, daily turning volumes are needed. However, the collection of daily turning volumes is difficult and impractical. To overcome this drawback, daily volumes can be estimated. The method chosen for this procedure was to collect daily volume counts on each intersection leg, collect turning movement counts for the intersection, and apply the fratar model to the turning movement counts with the daily volumes as the "in and out" (row and column) targets. It is desirable to collect a typical eight-hour turning movement count, covering AM and PM peak and midday periods.

The last piece needed to complete the procedure was to estimate future daily turning volumes. The estimation of "existing" daily turns again becomes a key element to the process, as they serve as the foundation for estimating future daily turns. Again, the fratar method can be used to estimate future daily turns, with existing daily turns as the "input matrix" and the estimated future daily intersection leg volumes as the in and out targets. (Application revealed that the fratar method for this task can be problematic if one or more intersection legs are forecasted to have low growth – decreasing turn volumes can result. For FDOT's software application, an optional procedure was included, in which the fratar model was used to estimate *additional* turn volumes, which were then added to existing to obtain the future estimate.)

The overall process is graphically illustrated in Figure 3. The process flows from beginning to end through a series of logical, understandable relationships, as a good predictive model should. In contrast, the common methods described earlier are more of a "black box", in which it is difficult to establish a logical flow of reasoning between input data and output values. This in itself is an additional advantage of the process. It lends itself to performing good reasonableness checks, including checks of the input data. For example, examining forecasted daily turning movements that are predicted partly on the basis of leg daily volumes, could lead one to reconsider the validity of the leg volumes if the turns do not seem reasonable.

Another advantage relates to the idea that "K" or "D" characteristics may change over time, because these characteristics are dealt with at a "smaller" level (i.e.: intersection paths versus links). It may be easier to make an assumption that these characteristics (one or both) would change on a particular turning path for example, than on a link. These kinds of changes would be related to changes in land use served by the travel paths, and in some cases, a particular turning path is easier to associate with a specific geographic area than a link. In essence, the method not only produces more logical results from its direct application, but also allows increased flexibility to take advantage of additional information that could improve the forecasts.

FDOT District Four Design Traffic Software Development

The results of our efforts to improve turning movement forecasts, along with efforts to improve other aspects of design traffic forecasting, are being combined into a software program known as the Design Traffic Engine (DTE). DTE will allow the development of design traffic forecasts for corridors with multiple intersections as easily as a single intersection. As part of the process improvements, DTE will generate reports automatically.

The data required to generate design traffic forecasts is substantial but generally available in various databases. These data include travel demand model(s) forecasts, historical counts, turning movement counts, and previous design traffic reports. An Integrated Design Traffic System (IDTS) is under development to provide a Geographic Information System (GIS) interface to access existing databases, previous design traffic reports, the DTE, and to store new reports. We hope to release both the DTE and IDTS in 2000.

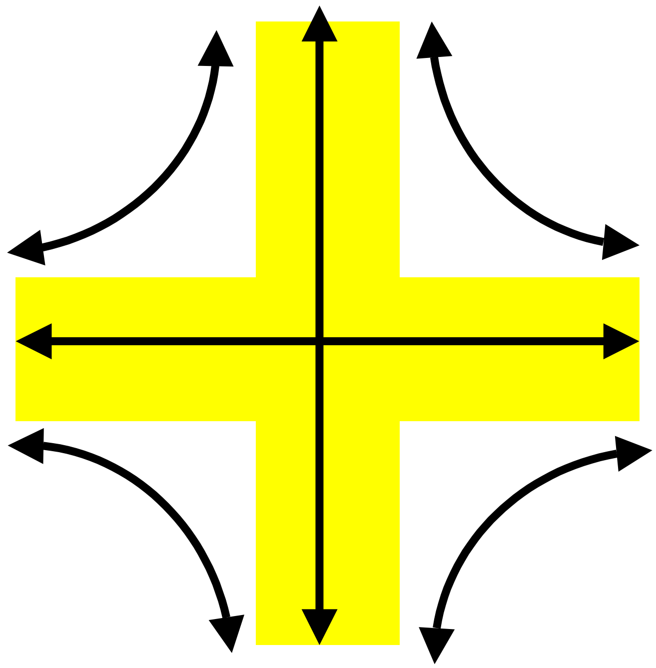

Figure 1. Intersection Turning Paths

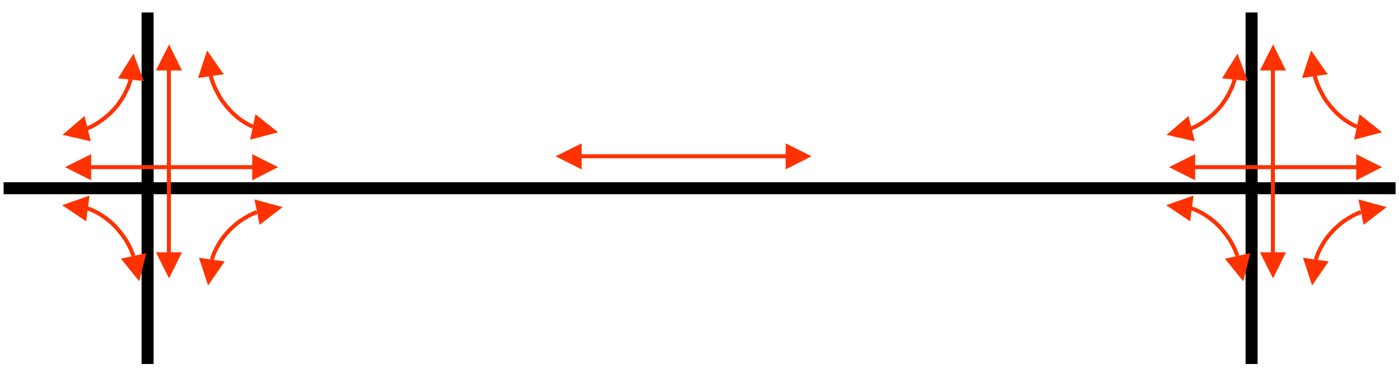

Figure 2. Relationship of Link to Intersections

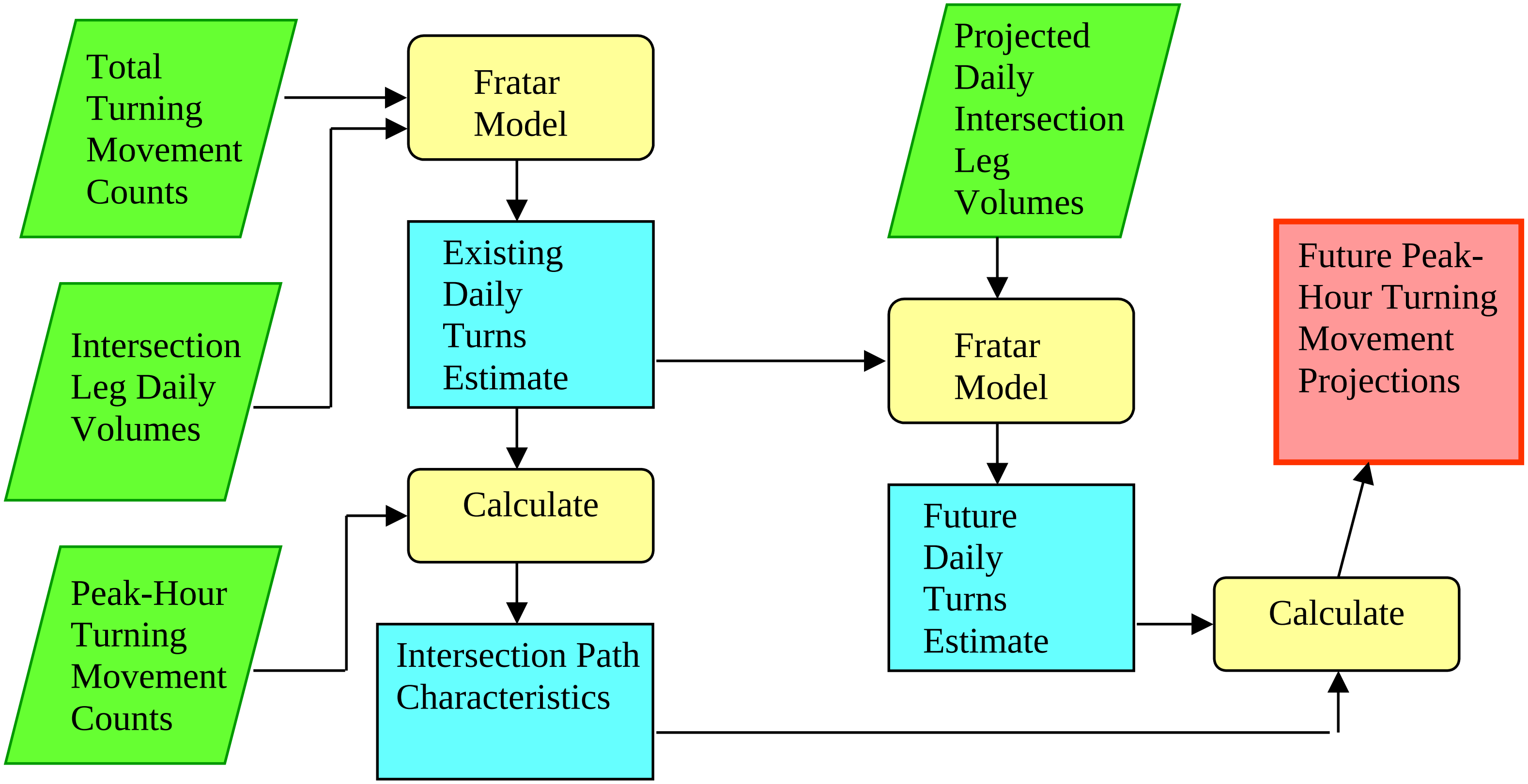

Figure 3. Path-Based Intersection Turning Movement Forecasting Process

Integrated Regional Transportation Modeling for the Evaluation of ITS Impacts: Methodology and Results from a Seattle 2020 Case Study

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Abstract

The objective of this recently completed study is to conduct a shadow major investment study that explicitly measures the impacts of ITS technologies on regional transportation. The study features a case study based on the Seattle metropolitan area sponsored by the FHWA ITS Joint Program Office (JPO) and is conducted with oversight on the part of the Puget Sound Regional Council (PSRC) and the Washington Department of Transportation.

The congested I-5 corridor north of the Seattle central business district forms the basis for the case study. Travel demand for the year 2020 is taken from regional estimates. Networks were then developed for two modeling packages: EMME/2, a transportation planning "four-step" model, and a variant of the INTEGRATION Ver. 1.5 meso-scale traffic simulation. ITS elements (including ATIS, ATMS, and APTS components) are represented from six different alternatives in the two models.

The simulation-based network is exercised for each alternative through a series of 22 representative scenarios. The scenarios were derived from a cluster analysis of traffic flow data (for variations in travel demand) and weather/incident impacts (taken from historical archives). Each scenario has a weight or probability of occurrence and the scenarios taken together comprise a representative year of operation.

Measures of effectiveness generated from the two models include: travel time, corridor throughput, travel delay, vehicle-kilometers traveled (by speed range), number of vehicle stops, mode split (by 15-minute time period), and HOV facility usage. The impact of the alternatives on overall regional travel may be compared with localized impacts within the study corridor itself. Impacts from the simulation-based evaluation may be compared with the impacts predicted by the regional model by rolling up impacts over all scenarios weighted by each scenario's probability of occurrence.

Key results from the analysis include a roughly 30% reduction in trip time variability for alternatives including ITS technologies, an overall reduction in stops per vehicle-km of travel in the corridor, and an increase in annual effective throughput for the corridor of 4-10%.

Innovations in Forecasting Commuter Rail Patronage

Bernard Alpern, *KPMG*

Abstract

This paper describes the development and application of incremental logit models for the projection of future demand for commuter railroads in the Buenos Aires metropolitan area. The work was performed on behalf of a private operator of commuter railroads in Argentina, who is planning major improvements to these railroads, and required high-quality projections of future ridership to obtain financing for the improvement program.

The proposed improvement program is virtually a complete overhaul of the current infrastructure. The improvements will be experienced by train users not only in terms of greatly improved train travel times and service frequencies, but also as the result of replacement of the current rolling stock with modern, much more comfortable coaches, major renovation of stations to provide modern facilities and high-level platforms, and provision of a new connection to the Buenos Aires subway system.

In the absence of a regional travel demand model for the Buenos Aires metropolitan area, it was decided that the projections would be developed using incremental logit models to estimate changes in commuter rail market shares which would result from the proposed service improvements. Stated-preference surveys were used to determine the sensitivity of travelers to various attributes of commuter rail service. In addition to sensitivity to changes in travel time, service frequency, and fare, the surveys were also used to determine sensitivities to other attributes such as quality of rolling stock, station amenities, and seat availability.

While the railroad with the history of security problems has experienced great improvement in this area, and more improvement is expected, surveys show that usage of this railroad is greatly affected by the lingering perception that it is very unsafe to use. In order to reflect this in the projections, data from the surveys were used to estimate the magnitude of the bias against this railroad, which was attributed to the perception of unsafe conditions. It was then assumed that this bias would gradually dissipate over time. The rate of dissipation can be increased through implementation of an effective public information campaign, resulting in accelerated growth in ridership.

This study demonstrated that well-designed stated preference surveys can be used to estimate the sensitivity of travelers to improvements in comfort and amenities. Further extensions of this work could further explore sensitivity to issues such as personal security, reliability of service, and accessibility to stations.

Modeling Transit Demand in the Big Apple from a Transit Agency Perspective

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MTA New York City Transit

Abstract

MTA New York City Transit has developed a network model of the New York City subway and bus system within a GIS based travel demand modeling package. It has been applied for major corridor studies including the DEIS for a possible Second Avenue Subway and service planning for major service disruptions due to reconstruction. The emphasis is on capacity constrained trip assignment within a dense transit network The regional and organizational context within which the model is being applied is described, including the coordination with numerous regional transit studies underway within the New York MTA Region. The specifics of the model are presented including routes, stops, a CBD walk network, timed subway-to-subway transfers, the zone system and the trip table. The GIS based software package is described along with details and benefits of the stochastic user equilibrium transit network assignment procedure. The corridor studies and reconstruction service planning applications are explained. The paper concludes with a look at future challenges including transitioning to a major software upgrade and using electronic farecard (MetroCard) transaction records to develop and improve the accuracy of trip tables by time of day.

Introduction

MTA New York City Transit, the agency responsible for all subway and most bus service in New York City, has developed a network model of the New York City subway and bus system within a GIS based travel demand modeling package. This paper describes how transit demand is being modeled with specific examples from corridor studies and short term service planning for service disruptions due to reconstruction. There are four major topics:

1. Context: Regional and Organizational
2. Modeling: Transit Network Building and Trip Assignment
3. Applications: Traditional Corridor Studies and Reconstruction Service Planning
4. Future Challenges: Software Upgrade and Improved Trip Tables

Context

New York City has one of the largest subway and bus systems in the world and is further served by numerous commuter rail and bus lines from surrounding areas. Most of the subway lines have local and express routes to choose from and there are numerous subway line-to-subway line transfer locations, further adding to the choices available to customers. These size and complexity issues pose a significant challenge for model building and calibration while at the same time they demonstrate the need for a systematic way to determine the best ways to serve a changing and growing travel market. The model needed to be tailored to both the needs of the regional planning process for federally funded projects and the internal operating needs of New York City Transit.

The regional context includes coordination with the New York Metropolitan Transportation Council (the local MPO) and the Metropolitan Transportation Authority (MTA), the regional transit agency. The key elements were the use of a consistent set of socio-economic forecasts and consistent modeling assumptions within the MTA family:

- The MPO developed and approved county level population and employment projections and provided county-to-county journey-to-work projections.
- The MTA established a "Long Range Planning Framework" for coordinating regional transit studies and modeling methodologies.

Figure 1 shows the relationships among the MPO, the MTA and the numerous transit studies underway or recently finished. The organizational context centers around the establishment of a small but experienced modeling group within the transit operating agency, New York City Transit (NYCT). The location of the modeling group within the operating agency was a critical factor in the success of the modeling effort for the following reasons:

- The corridor studies as well as the reconstruction projects were primarily directed and managed from within New York City Transit.
- It fostered a working relationship with individuals in NYCT's Operations Planning and Capital Program Management (i.e., engineering and construction) departments who directed and managed the corridor and reconstruction projects. This, in turn, enhanced NYCT's working relationship with consultant team members.
- Model development and production of results benefited from the internally generated project needs and pressures.

For Operations Planning, our role focuses on developing and coding alternatives service plans and selecting the optimum plan. The Capital Program Management department utilizes model output for cost-benefit analysis of proposed capital projects and to assist in selecting alternatives.

Modeling: Transit Network Building

A GIS based network of New York City subway and bus routes was developed over several years and connected to a zone system composed of census tracts and split census tracts. A.M. peak hour service levels and routes were coded:

- 25 subway lines, 225 NYCT bus routes, 84 private bus routes and a CBD walk network (Figure 2)

- 494 rail stations and 10,785 bus stops with intermodal transfer links and timed subway-to-subway transfers

- A.M. peak hour routes, headways and passenger carrying capacities

The zone system for the network model totals 2,355 zones that are composed of census tracts or census tracts split along block group lines. This system of small census based zones was chosen for the following reasons:

- The base year trip table was derived from the 1990 Census Journey-to-Work Package (CTPP)

- The large number of existing transit trips spread throughout the city made the use of small zones feasible

- Small zones were needed to improve the distribution of trips among closely spaced subway and bus routes

The capacity constraints on many subway and bus routes mandated a peak hour model and this required the development of an a.m. peak hour trip table. The methodology for generating this table is summarized as follows:

- The peak period tract-to-tract journey-to-work data from the 1990 Census (CTPP-Part 3) was the primary source for the trip table. Peak period as defined by the Census was time leaving for work between 6:30 a.m. to 8:29 a.m. Primary modes "subway" and "bus" were used.

- These peak period trips were converted to peak hour trips using CTPP Part 1 data on time leaving for work by mode by residence tract. For example, the CTPP Part 1 data might show that 60% of the peak period workers that live in a tract and use public transportation leave between 6:30 a.m. and 7:29 a.m.

- The resulting peak hour trip tables for subway and bus were updated and calibrated to 1995 conditions using weekday ridership counts, including peak period station entries counts and peak load point leave load counts.

The software used is TransCAD, a combination Geographic Information System (GIS) and Transportation Analysis package. The GIS was essential for coding and visualizing routes and for demographic analysis. For transit trip assignment, the package includes a stochastic user equilibrium (SUE) methodology that was specifically designed for areas like New York City that have closely spaced parallel routes and routes with express and local service. A random error term is introduced to smooth out the distribution of passengers among these lines to better replicate actual passenger choices between the parallel routes or the express and local routes.

Modeling: Trip Assignment

The focus of trip assignment modeling for NYC Transit is usage of the subway system where many lines are operated close to track capacity and several operate with passenger loads that exceed adopted service guidelines. In the case of the Lexington Avenue Subway, not only does the express operate with passengers loads in excess of guidelines but the local is heavily used and the many bus routes that run above it or on parallel avenues are also heavily used. The average weekday ridership on the Lexington and Third Avenue bus routes (M101, M102, M103) is 70,000 passengers and on the nearby M15 (1st and 2nd Avenues) its 63,000 passengers. For most NYCT projects the first modeling objective is to determine the contribution of the project toward reduction in peak hour crowding. For this reason, the model was built with a.m. peak hour service and trip tables and calibrated with a.m. peak hour peak load point counts.

The stochastic user equilibrium (SUE) trip assignment method within TransCAD addresses the capacity and route choice as follows:

- Accounts for capacity constraints through crowding penalty function

- Accounts for availability of multiple path and route choices (e.g., local vs. express, subway vs. bus) with the stochastic feature that introduces a random cost penalty to prevent the imbalanced loadings common to all-or-nothing assignments.

- As computer speeds and memory improved, the number of iterations that could be run overnight increased from 20 to 40 iterations. By 40 iterations the reduction in the maximum link volume change is largely completed. This allowed for the model to be run overnight on a daily basis with output ready in the morning.

Replicating the choices passengers make when traveling by transit in NYC requires careful use of the following calibration factors:

Applications: Traditional Corridor Studies

The transit network model has been applied to two corridors serving the Manhattan Central Business District. The East River Crossing Study was a Major Investment Study (MIS) and the Manhattan East Side Alternatives (MESA) study was a combined MIS and Draft Environmental Impact Statement (DEIS).

The East River Crossing Study focused on subway service using the Manhattan Bridge which connects Brooklyn with Manhattan via four subway tracks and six highway lanes. Only two of the subway tracks have been useable for most of the last 14 years due to deferred maintenance and structural problems arising from the original bridge design. Even after the extensive rehabilitation currently underway is completed and full four track service is restored, periodic service outages for maintenance are likely on a fairly regular basis. The impact of full or partial closure of the subway tracks on subway crowding, travel times and required transfers was modeled for No Build conditions and a long and short list of TSM and “Build” alternatives.

All alternatives were modeled under four Manhattan Bridge Scenarios: north side of bridge open (existing condition), south side of bridge open, bridge fully open and bridge fully closed. This greatly increased the total number of model setups and runs required but it was the best way to examine alternatives given the bridge's uncertain future. The modeling was further complicated by the service improvement options included within each alternative as shown in Figure 4. MBA5 was selected as the recommended alternative. Model output for the bridge closed scenario indicated a potential savings of 4,600 peak hour passenger hours and a 2,400 reduction in crowded passenger hours during the peak hour.

The Manhattan East Side Alternatives (MESA) study was a combined MIS and DEIS for resolving crowding and congestion problems in a corridor containing the heavily used Lexington Avenue Line ("4", "5" and "6" routes) and the potential route of a Second Avenue subway. This study required careful coding and calibration of subway and bus service in Manhattan and the Bronx so that the model could provide reliable estimates of passengers diverted to new services.

The preferred build alternative under consideration is a Second Avenue Subway from 125th St. and Lexington Avenue over to Second Avenue and down to 63rd St. where it connects with the 63rd St. line. The route continues across 63rd St. and then connects with the four track Broadway BMT line serving the west Midtown Manhattan CBD, the Times Square theatre district, Penn Station and the Downtown Civic and Financial centers.

A critical link analysis of the route shows a wide market area of trip origins likely to use the route (Figure 5). The model results for this build alternative indicated a significant reduction in crowding on the Lexington Avenue Express ("4","5"), a primary objective of the project. Passengers at the primary peak load point (86th St.) were reduced from 35,000 to 30,000 during the a.m. peak hour. Major travel time improvement were also reported by the model as indicated in Figure 6.

Applications: Reconstruction Service Planning

Passenger diversions were modeled for two major subway reconstruction projects, the Lenox Avenue Line ("2", "3" routes) Reconstruction and the Williamsburg Bridge ("J", "M", "Z") Reconstruction. In both cases, subway and bus service planners within the Operation Planning unit requested the diversion estimates to assist in developing service plans to accommodate thousands of affected passengers.

Modeling was done similar to the way it was done for corridor studies with a "no additional service scenario" setting the stage for evaluating the proposed service plans. The Lenox Avenue Line reconstruction required a shutdown of one subway track, permitting peak direction service to be run on the other track. Passengers traveling in the non-peak direction could use alternate subway routes and backtrack into the Central Harlem area or use an existing bus to reach their final destination, A series of shuttle buses were proposed within Central Harlem to ensure access to and from homes and institutions. The final plan was run and the model's estimates of passengers per route indicated that all passengers could be accommodated. The service plan (along with measures to ensure the reliability of alternate subway routes) was put in place during the reconstruction in 1998 and it helped make the project a major success. Reports from the field indicated that ridership estimates were on target.

The Williamsburg Bridge Reconstruction Project shuts down “J”, “M” and “Z” subway service over the bridge from May to October 1999 and affects 13,000 peak hour and 45,000 daily riders. Three major alternate subway routes were projected to carry the diverted passengers into Manhattan as follows:

- “L” route: 4,400 a.m. peak hour passengers
- “A/C” routes: 3,500 a.m. peak hour passengers
- “E/F” routes: 2,200 a.m. peak hour passengers

Because many diverted passengers would be taking buses to reach these alternate subway routes, a substantial amount of time was spent on checking and enriching the coding of bus routes, stops and transfers to and from the subway routes. Estimates of the use of these bus routes were used by the Operations Planning Division to help determine the amount of additional service to schedule. Early reports from the first week of the bridge shutdown indicate that the model’s estimates were accurate.

Future Challenges

There are three challenges that if met successfully will significantly improve our ability to provide demand modeling services internally and within a regional context:

- **Upgrade to TransCAD 3.5:** This includes conversion of network databases to the “Route Systems” format, enhancements to route editing and path skimming. A “route system” is a map layer that contains a collection of routes that are defined by an underlying layer of streets, highways or rail structures. Stops or mileposts can be included on each route. The displaying of routes is facilitated by offset and tracking options that are used to separately display routes with common links or group routes that share one track. The converted databases are currently being tested for use internally and by other agencies including the local MPO (New York Metropolitan Transportation Council) which is using TransCAD 3.5 as the modeling package for its new “Best Practices Model”.

- **MetroCard Based Trip Tables:** Subway station entry and exit counts by 15 minute intervals can be tabulated from NYC Transit’s systemwide automated fare collection (AFC) system, i.e., MetroCard. These data will be used to update and improve the model’s a.m. peak hour trip table and to develop trip tables for other time periods. This will help to account for ridership growth in the 1990’s and travel changes due to free subway-to-bus transfers starting in July 1997 and passes starting in January 1998:

  - Combined subway and bus ridership in 1998 was up 14.5% from 1996 to 1,829 million

  - From 1992 to 1998 combined subway and bus ridership increased by 19% on weekdays and 32.8% on weekends

- **Service Planning:** Work will continue with other departments to help them use modeling results for applications such as route and service modifications, scheduling major reconstruction projects (General Orders) and improve path building in a new internet based passenger information system. The model will also be useful for examining ways to add service and equipment to meet the needs of a growing ridership base.

Conclusions

MTA New York City Transit's in-house development and application of a transit trip assignment model for both the subway and bus systems in New York City has been successful for both traditional corridor studies and for developing service plans for passengers diverted from their normal routes by reconstruction projects. Including a highly detailed and precise representation of the transit travel choices available within the city was critical as was the selection of a modeling software package that is based on a Geographic Information System (GIS). The location of the modeling staff within the operating agency greatly facilitated close working relationships with service planners and capital investment analysts that are essential for the successful application of the model as a planning tool.

The potential for significant improvements in transit trip tables exists in data generated by the MetroCard fare card system. Station entry and bus boarding transactions that include time and MetroCard serial number are recorded daily. The feasibility of matching two or more successive transactions on one card to derive origin and destination data is currently being explored. The recording of time information will contribute to the development of non-peak trip tables as well.

Figure 1
Regional Context

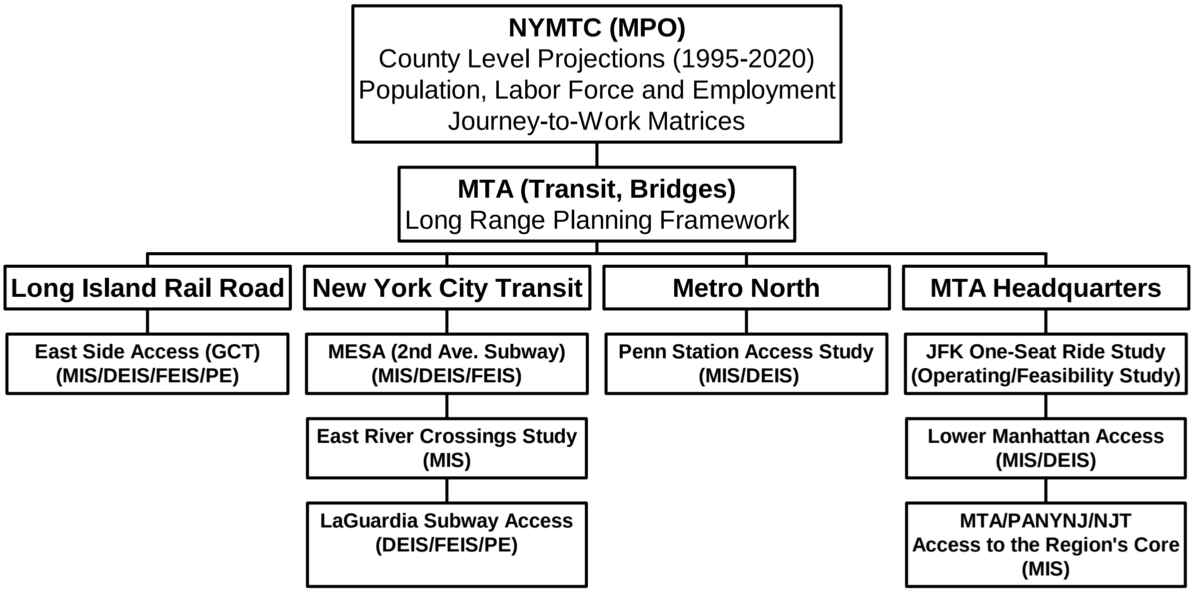
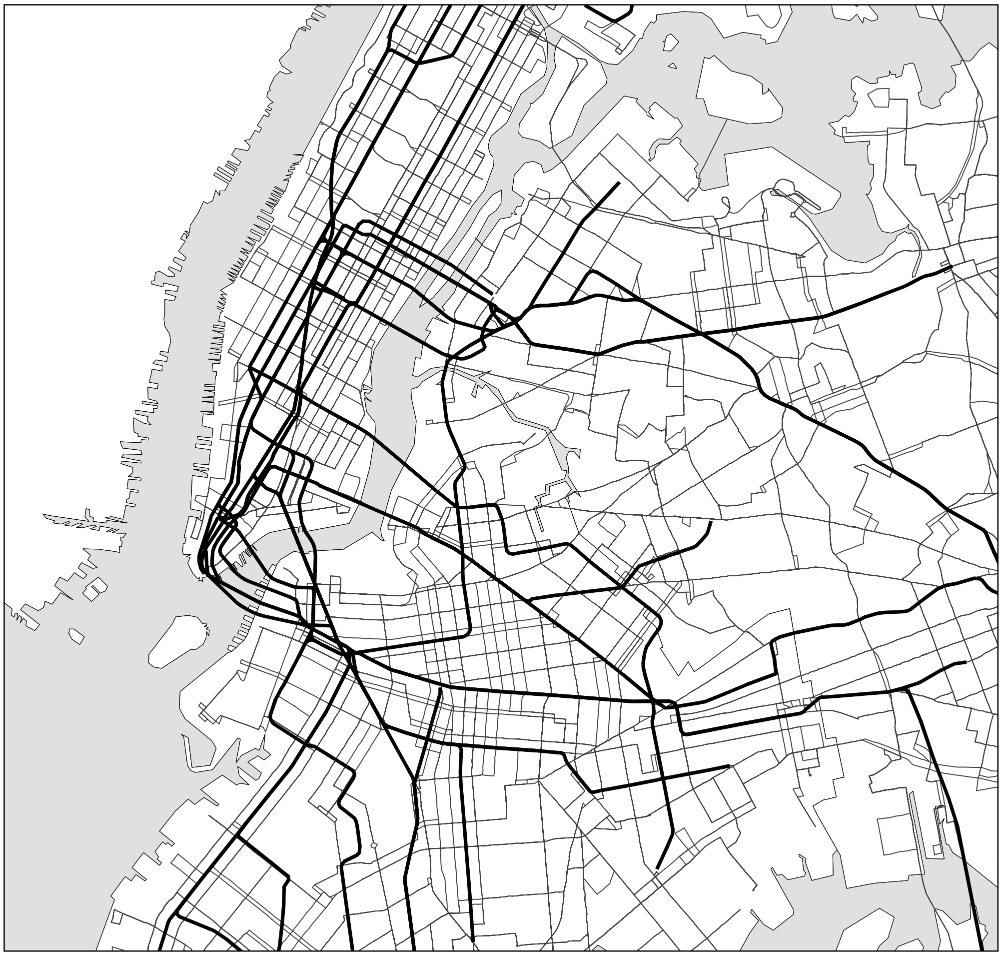


Figure 2
Portion of NYC Transit Network



Subway: ▬▬▬ **Bus:** ——

Figure 3
Modeling Passenger Behavior

Calibration Factors			
Link Type	Variable	Factor	Explanation
Route Links (subway only)	Passenger carrying capacity	1.15	guideline capacity of 3.0 square foot per standing passenger increased to reflect behavior
Route Links	Wait Time	2.0	Waiting time doubled relative to in-vehicle-time
Route Links	Fare in cents	.06	Cost of $1.50 fare in minutes is 9.0
Transfer Links	Walking time at 2.0 mph	1.50	Walking time increased 50% relative to in-vehicle time

Figure 4
East River Crossing Study
Final Short List of Alternatives for Manhattan Bridge Service

Alternative	Service Components
No Build	
TSM	• Bus Service/HOV Lanes on Manhattan Bridge • Revise Service Patterns at Canal Street • Lengthen "3" Route Trains • Passenger Transfer between Lawrence St./Metro Tech and Jay St. Stations • Passenger Transfer between Broadway-Lafayette and Bleecker St. Stations (Northbound "6" Route)
MBA2	• Rutgers St. Subway Tunnel/ DeKalb Ave. ("B", "D", "N" and "Q" Routes) Track Connection • Passenger Transfer between Lawrence St./Metro Tech and Jay St. Stations • Revise Service Patterns at Canal Street • Nostrand Junction/Flatbush Terminal Improvements • Lengthen "3" Route Trains
MBA5	• Rutgers St. Subway Tunnel/ DeKalb Ave. ("B", "D", "N" and "Q" Routes) Track Connection • Revise Existing Service Patterns on "D", "Q, "N" and "M" Routes • Lengthen "3" Route Trains • Passenger Transfer between Lawrence St./Metro Tech and Jay St. Stations • Passenger Transfer between Broadway-Lafayette and Bleecker St. Stations (Northbound "6" Route)
MBA8	• Nostrand Junction/Flatbush Terminal Improvements • Lengthen "3" Route Trains • Revise Service Patterns at Canal Street • Passenger Transfer between Lawrence St./Metro Tech and Jay St. Stations

Figure 5
Origins of A.M. Peak Hour Trips Using the Southbound Second Avenue Subway Leaving 72nd St.

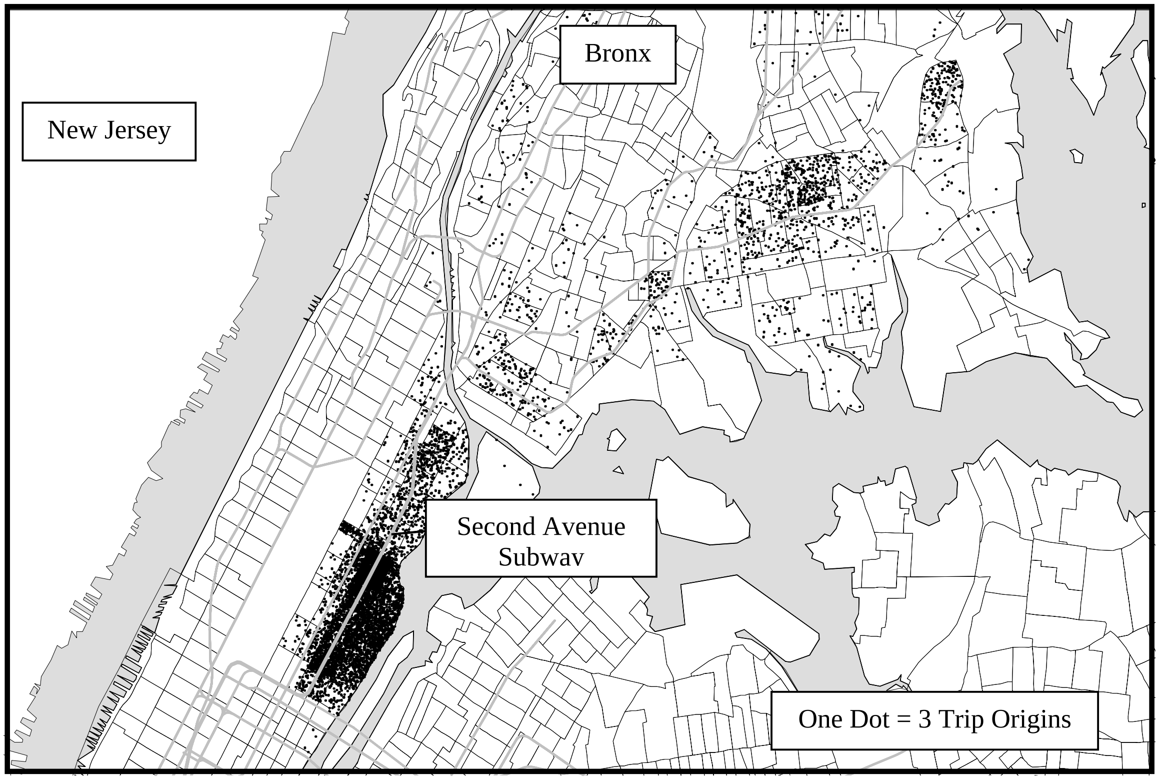


Figure 6
Major Travel Time Improvements
Second Avenue Subway North vs. No Build

Origin	Destination	No Build	2nd Ave. North
E. 86th St. between 2nd Ave. and 3rd Ave.	Times Square (W. 42nd St. and Broadway)	28 minutes	19 minutes
E. 110th St. between 1st and 2nd Ave.	Chelsea (W 23rd St. and 8th Ave.)	50 minutes	33 minutes
E. 86th St. between 2nd Ave. and 3rd Ave.	West Lower Manhattan	38 minutes	32 minutes

Capturing Income Effects on Transit Mode Choice and Assignment

Bruce Griesenbeck, *Sacramento Area Council of Governments*;
and Tracey Quintin, *University of California at Davis*

Abstract

Many travel demand modeling platforms ignore or distort the income effects in the modeling of transit mode choice and assignment. The fundamental reason for this is that the maximum utility transit path for a particular origin, destination, and income class may not in fact be the shortest time path. This problem can be serious when transit options with higher fares and lower travel times (e.g. commuter rail and some high-end express bus services) are modeled in the same alternative with lower fare/higher travel time options (e.g. a standard, urban fixed route service). Working around this problem is difficult, especially with travel demand modeling software which is limited to single shortest path, all-or-nothing transit assignment, or where the basic mode choice model does not explicitly account for these differences in transit service.

This paper describes a straightforward approach to solving this problem. The approach includes three basic steps, using a standard multinomial logit transit mode choice model including an inclome class variable, and a MINUTP model platform. The first step is splitting the transit network into two pieces, based on fares and level of service distinctions (e.g. standard fixed-route transit and commuter rail). The second step is tallying the source network for the maximum transit utility for each origin, destination and inclome class. The third step is splitting the final transit trip tables, and assigning trips to the correct (i.e. maximum utility) transit network. This approach would be of interest to travel demand modelers, transportation analysts and planners evaluating higher fare/lower travel time transit options such as commuter rail and deluxe express bus service.

The paper presents the results of using this approach for a test network in the Sacramento metropolitan area. The results include: a comparison of an test analysis using the approach, with a standard approach not accounting for income effects; an accounting of the extra network development, computation, and analysis time in using the approach; and a qualitative assessment of the value of the approach. The approach was developed for use in a corridor study, which will include analysis of commuter rail options. Results of using the approach for the corridor study will be included in the paper and presentation, to the extent that they are available prior to the conference.

The Sacramento region is conducting an Interstate 80 MIS. I-80 runs east-west across the region between Davis on the western edge and Lake Tahoe on the eastern edge. The existing SACMET model was originally developed in the early 1990's, without the capacity to evaluate competing transit alternatives between the same origin-destination zones. In order to fairly evaluate transit alternatives within the region, a procedure was needed that was sensitive to income and cost considerations among households within the same origin zone. This paper describes the procedure that was developed, and presents preliminary results for a test case.

Problem Statement

The regional travel demand model, known as SACMET, does not allow for evaluation competing transit modes between origin-destination pairs. The only transit options included in the model are differentiated by mode of access (drive versus walk), and not by inherent characteristics of the line-haul transit modes. This was justified during the development of the model because the types of transit options available at the time, and the transit options contemplated for future implementation, did not vary significantly in terms of transit fare/travel time trade-offs. However, if a "premium transit" mode, which offers significantly decreased travel time at a higher fare, is considered, this limitation of the model is serious.

Background on SACMET Mode Choice and Transit Assignment

SACMET home-based work (HBW) mode choice is a nested logit destination/mode choice model. (See Figure 1.) The destination choice model is the upper nest of the model and uses the logsum from the mode choice model. The logsum is a variable that uses all the time and cost considerations for each possible mode.

The mode choice model is the lower nest and is a multinomial mode choice model with the following seven alternatives: drive-alone, two-person shared ride, three or more-person shared ride, walk-access to transit, drive-access to transit, walk, and bike. The mode choice model incorporates market segmentation techniques to split households within each zone into low, middle and high income-per-worker classifications.

Currently, the model set-up runs separate transit skims for walk-access and drive-access to transit. This produces a skims of the best travel time for transit to be used within the mode choice model. The mode choice model then produces two trip tables of drive-access and walk-access to transit, which are based on the utility of that mode. The utility of a mode is composed from calibrated coefficients which trade off the value of time to the cost of the mode. The mode choice model is calibrated such that each traveler wants to maximize their utility. This generally requires a trade-off between time and cost. Usually, a faster travel time is more expensive, and conversely a slower travel time costs less.

When this trip table is then assigned to the transit network, the shortest-time-path is chosen for each origin-destination pair for all trips for that zone pair. If there are competing transit modes, which is often the case when drive-access to a premium transit mode is available, only one mode will be chosen per origin-destination pair based on the best travel time. This assignment process completely ignores the cost consideration of the traveler. The final assignment then is unreliable, as unreasonable swings in boardings may occur based on this all-or-nothing approach.

Proposed Premium Transit Submodel Procedure

The premium transit submodel (PTS) procedure attempts to work within the existing structure of the SACMET HBW mode choice model, and allow for a fair evaluation of competing transit alternatives based on travel time, fare, and household income class.

First, any competing transit alternatives are identified and separated into different transit files. In general, this involves providing PNR access to long-haul transit service, such as light-rail, express bus and commuter rail. Then a transit skim is done for each identified mode.

The mode choice model is used to compute a utility for each possible transit-drive option for each income group. The option which provides the maximum utility for that income group is identified and used within the mode choice model, and an accounting kept of the number of trips per mode. This provides trip tables of drive-access to transit for each competing mode, based on maximizing the utility of the traveler. A flow chart for the PTS procedure is shown in Figure 2.

The PTS was implemented using modified SACMET program files for the HBW mode choice model, and an additional stand-alone program which compared the transit utilities for each transit option by I-zone, J-zone, and household income class (IJH) combinations, and generated a tally matrix. The tally matrix included an IJH code, the maximum transit-drive utility, and the source line file for the maximum utility. This matrix was used later to calculate the overall HBW mode split, and to allocate transit-drive trips the the maximum utility transit line file for assignment.

This procedure can be used for walk-access to transit, although the incidences of competing transit modes for walk-access to transit are probably rare in this region. Most walk-access to transit trips are made on local transit, as opposed to premium transit modes such as express bus or light rail.

PTS Test Case Results

The test case included three transit options: standard urban transit (A1); express bus (A2); and commuter rail (A3). The PTS focused on drive-access only. A1 includes drive access to standard light rail transit and commuter buses, with fares generally around $1.25. A2 includes limited stop express bus, with marginally faster line haul times than A1 and fares ranging from $2.00 to $3.50. A3 provides significantly faster travel times than either A1 or A2, with fares ranging from $2.50 to $5.00. Table 1 provides a comparison of the travel times and fares for the three options for selected I-J pairs. An area map is provided in Figure 3.

Figure 4 shows a comparison of the utility computations for the three transit options, cross tabulated by household income class. As expected, commuter rail provided the maximum utility for the high income households for four times as many IJH combinations as the middle income households, and sixteen times as many for low income households. The express bus option generated the maximum utility at the highest rate for middle income households, but the differences by income class were not as striking as they were for commuter rail.

Table 2 summarizes the PTS results in overall mode choice and transit assignment, compared against two other cases. The base case for comparison purposes included all three transit options in one line file, which maximized the potential for discrepancies between the the shortest time paths used for skimming and assignment. A null alternative was also used, which included only option A1, and neither the express bus nor commuter rail alternatives.

In general, the PTS affected total mode split only slightly. Total transit-drive trips varied by less than one percent between the test case, base case, and null alternative. Transit assignment, measured by total boardings, did show significant differences. For the commuter rail alternative, twelve times as many trips were assigned in the base case as compared to the test case (681 versus 57). This illustrates the classic problem of over-assignment of a premium transit mode, if fares are not taken into account in the assignment process.

The fact that overall transit trips are lower in the base case, albeit only slightly, illustrates another limitation of ignoring income effects of fare and time trade-offs in a single-shortest-path transit assignment model. If fares are ignored in path building and skims, but accounted for in the utility computations for mode choice, some of the maximum utility paths will be missed, especially for lower income households. Thus, while premium transit modes may be overassigned, overall mode split is likely to be under-estimated.

It should be noted that while PTS does account for income effects on travel time/transit fare trade-offs, the inherent characteristics of premium transit options themselves are not accounted for.

Summary

The PTS procedure provides a way to efficiently account for the income effects of transit mode choice, and carry this through to assignment in a single-shortest-path model. The procedure eliminates the problem of over-assignment of premium transit modes. However, since the model only looks at trade-offs between travel time and fare by income class, inherent characteristics of premium transit modes are not accounted for.

Table 1: 2010 Test Alternatives: Selected I-J Pairs to Sacramento CBD

SACMET Premium Transit Submodel (PTS)

A1: Drive Access to LRT (Placer) or Bus (Davis)

From:	Fare	OVTT		IVTT		Tot TT	
		Min	Max	Min	Max	Min	Max
Davis	$1.20	21	34	18	28	40	59
Roseville	1.00	9	23	32	41	41	64
Auburn	1.00	9	23	50	59	59	82

A2: Drive Access to Commuter Bus

From:	Fare	OVTT		IVTT		Tot TT		Differences from A1: Fare	Tot TT	
		Min	Max	Min	Max	Min	Max		Min's	Max's
Davis	$2.00	15	31	17	21	40	57	$0.80	0	-2
Roseville	2.50	15	27	28	35	50	64	1.50	9	0
Auburn	3.50	15	27	49	56	71	85	2.50	12	3

A3: Drive Access to Commuter Rail

From:	Fare	OVTT		IVTT		Tot TT		Differences from A1: Fare	Tot TT	
		Min	Max	Min	Max	Min	Max		Min's	Max's
Davis	$2.50	16	31	17	17	33	48	$1.30	-7	-11
Roseville	3.50	16	31	26	26	48	56	2.50	7	-8
Auburn	5.00	16	31	46	46	61	56	4.00	2	-26

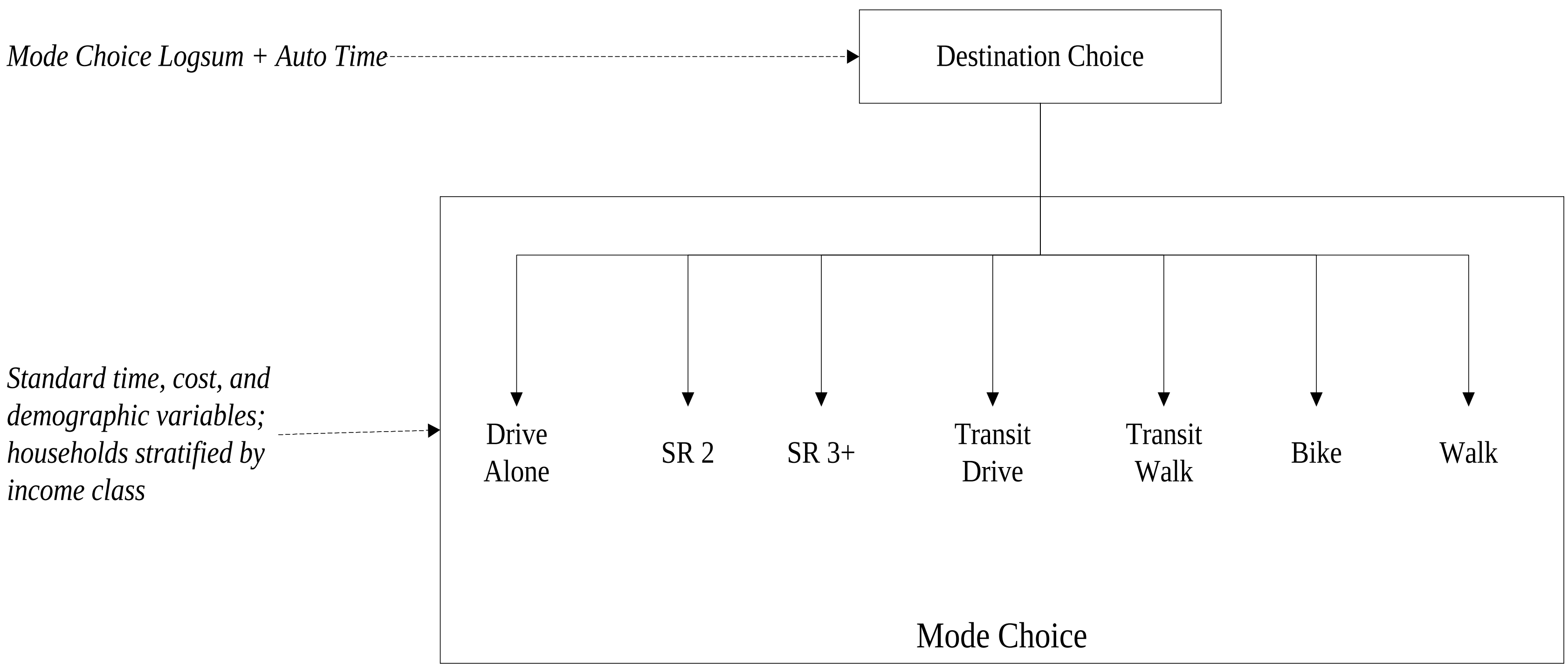
Note: These alternatives are for test purposes only, and are not intended to represent any actual project proposal.

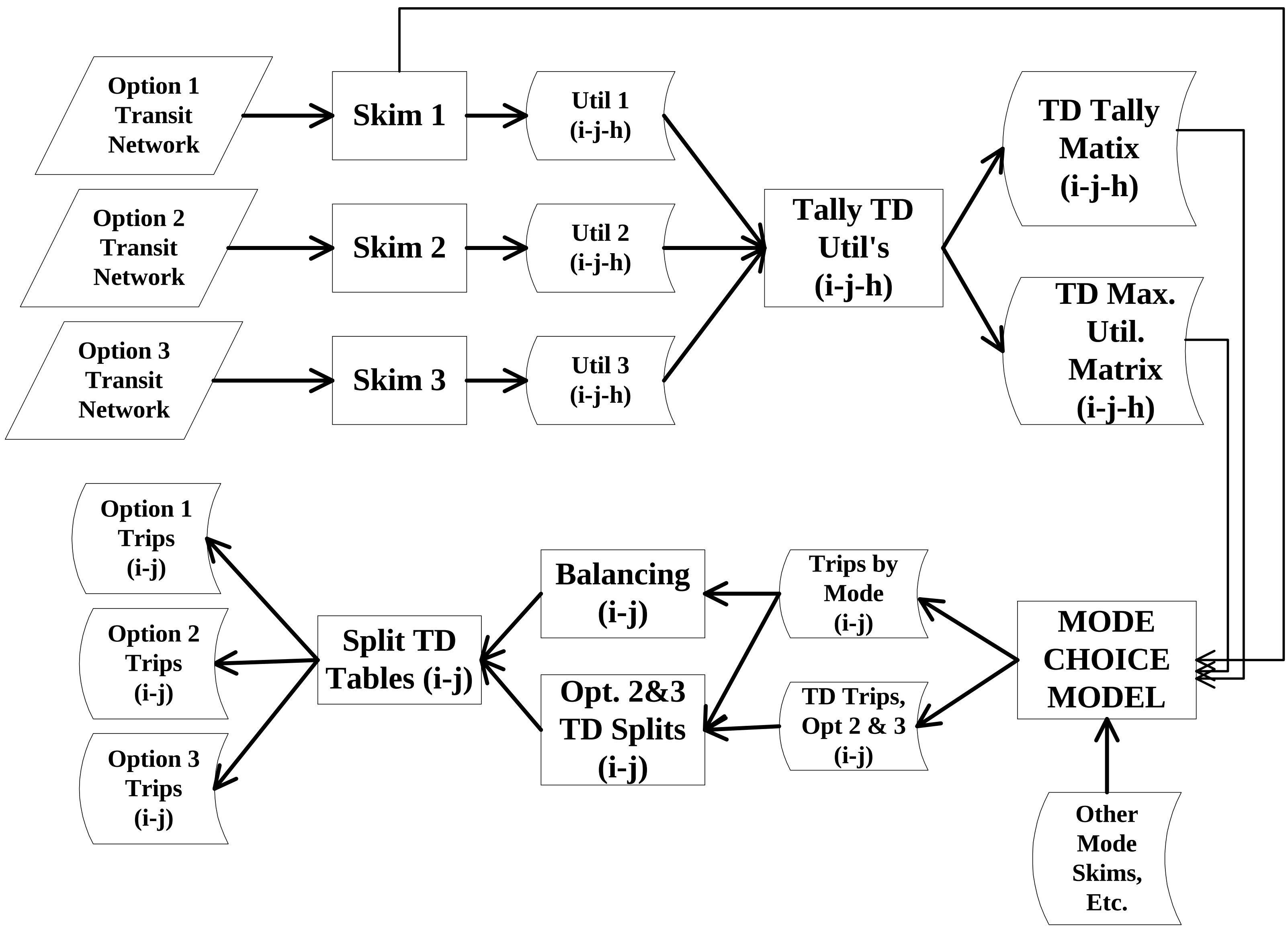
Table 2: Comparison of HBW Person Trips by Mode, HBW Transit Boardings

SACMET Premium Transit Submodel (PTS)

	Mode	Test Case: w/PT Submodel	Base Case: w/Opt's, w/out PTS	w/PT v. w/out PT Ratio	Diff.
HBW Daily Person Trips	Drive alone	1,153,841	1,153,909	1.00	-68
	2-Person Shared Ride	170,100	170,126	1.00	-26
	3+ Person Shared Ride	44,909	44,917	1.00	-8
	Transit-Walk Access	28,564	28,548	1.00	16
	Transit-Drive Access	20,003	19,920	1.00	83
	A1: Conventional	19,903	n/a		
	A2: Commuter Bus	43	n/a		
	A3: Commuter Rail	58	n/a		
	Transit-Drive Access Subtotal	20,004	n/a		
	Walk	36,162	36,159	1.00	3
	Bike	23,670	23,668	1.00	2
	Transit				
Transit Boardings	Transit-Drive Access				
	A1: Conventional	19,900	19,209	1.04	691
	A2: Commuter Bus	37	27	1.37	10
	A3: Commuter Rail	57	681	0.08	-624
	Transit-Drive Access Subtotal	19,994	19,917	1.00	77

FIGURE 1: SACMET HBW MODE/DESTINATION CHOICE MODEL




Option 1 Transit Network
Skim 1
Util 1 (i-j-h)
Option 2 Transit Network
Skim 2
Util 2 (i-j-h)
Option 3 Transit Network
Skim 3
Util 3 (i-j-h)
Tally TD Util's (i-j-h)
TD Tally Matix (i-j-h)
TD Max. Util. Matrix (i-j-h)
MODE CHOICE MODEL
Other Mode Skims, Etc.
Trips by Mode (i-j)
TD Trips, Opt 2 & 3 (i-j)
Balancing (i-j)
Opt. 2&3 TD Splits (i-j)
Split TD Tables (i-j)
Option 1 Trips (i-j)
Option 2 Trips (i-j)
Option 3 Trips (i-j)

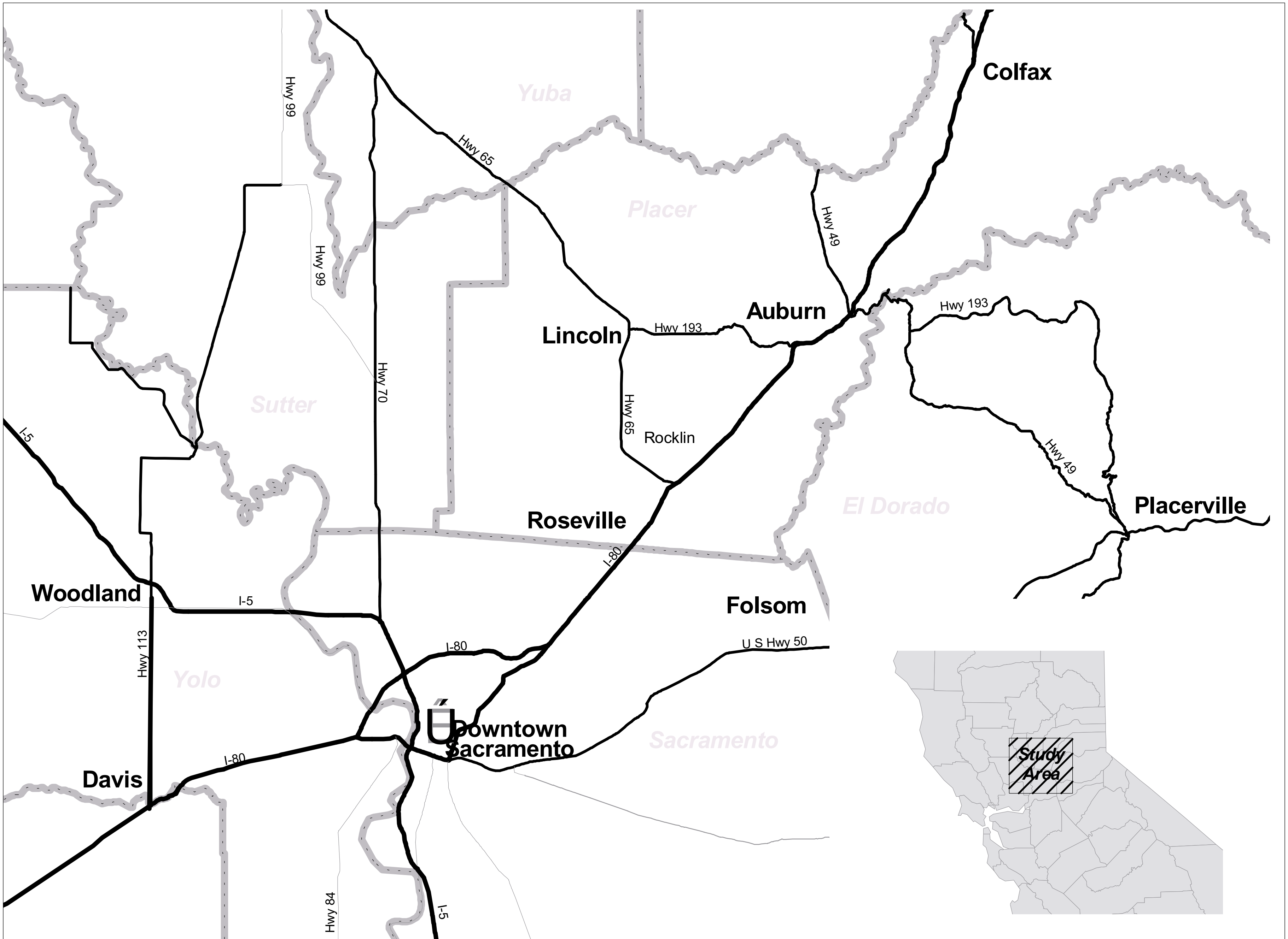
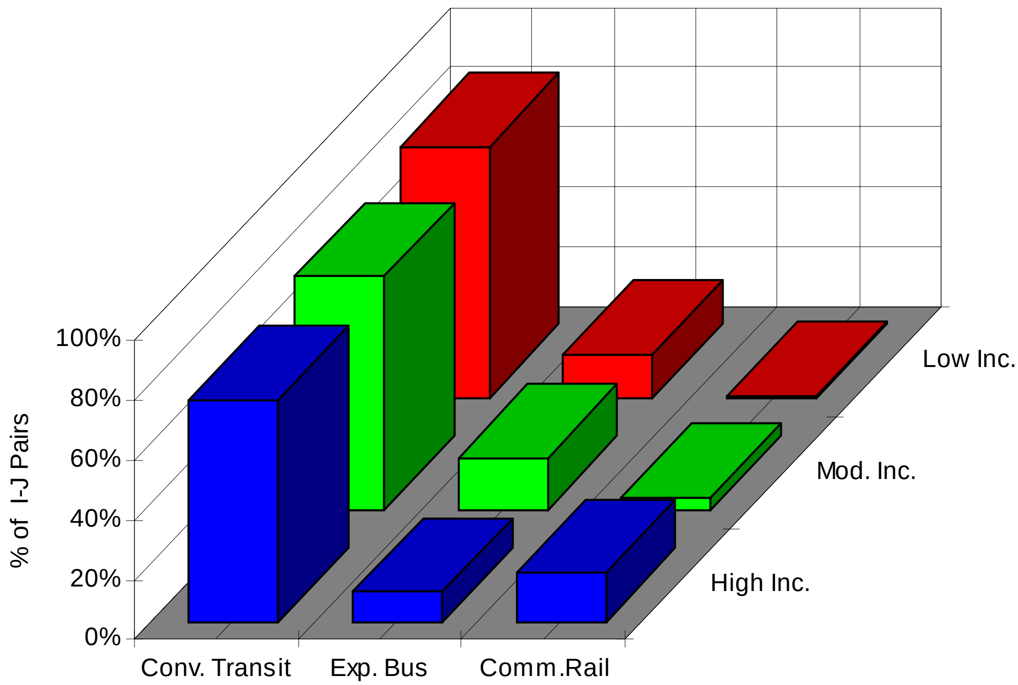


Figure 3:
Sacramento Region

March 1999
s:\gis\arcview\i80study\i80corr.apr
Laura Bell

FIGURE 4: Maximum Transit Utility
By Service Option And Income Class



How Valid Is It to Transfer Mode Choice Model Parameters?

Thomas F. Rossi and Maren L. Outwater, *Cambridge Systematics*

Abstract

It is common practice in the development of travel models in the U.S. to transfer parameters for logit mode choice models from models developed for other areas rather than to estimate the parameters from local survey data. In many areas, the lack of sufficient local data—either because a recent household travel survey has not been conducted or because the data collected are inadequate to estimate statistically sufficient parameters—has left little choice but to transfer parameters from another model.

The literature contains examples of previous efforts to document and compare mode choice model parameters estimated in different urban areas. Although these efforts date to the early 1990's, they focused primarily on models estimated from data collected in the 1960's and early 1970's. This reflected the lack of household travel survey activity in the late 1970's and 1980's. Despite the age of the data from which these models were developed, many areas still transfer parameters from these older models, and average coefficients from these models are often referred to in determining the "correctness" of models used in urban areas today.

There are now a number of mode choice models estimated from more recently collected data, and it is appropriate to reconsider the transferability of parameters from models estimated from data that are now more than two decades old. This paper describes the results of a comparison of key level of service parameters—including in-vehicle time, out-of-vehicle time, and cost—from several models estimated from household travel survey data. The comparison shows that there is a wide range of values for the level of service coefficients among the urban areas for which the models were developed. This conclusion implies that models estimated from local data may yield significantly different parameter values than those of transferred coefficients and, therefore, that models developed from local data are preferable to those using transferred coefficients.

The comparison also shows that the assumptions about the "correct" level of service parameters based on models estimated from local survey data are, for certain variables, not far off from the average values of coefficients estimated from more recent data. For other variables, the coefficient values are quite different from the older values. With consideration of comparisons to size and level of service, models using transferred parameters may still be used in areas where local survey data sufficient for model estimation are not yet available, or on an interim basis until models from local data can be developed.

Introduction

It is common practice in the development of travel models in the U.S. to transfer parameters for logit mode choice models from models developed for other areas rather than to estimate the parameters from local survey data. In many areas, the lack of sufficient local data—either because a recent household travel survey has not been conducted or because the data collected are inadequate to estimate statistically sufficient parameters—has left little choice but to transfer parameters from another model.

The literature contains examples of previous efforts to document and compare mode choice model parameters estimated in different urban areas. For example, the report *Short Term Travel Model Improvements* [2] reported work by Schultz comparing travel time and cost coefficients for models estimated for various urban areas in the U.S. from 1960 to 1984. Although these earlier efforts to document and compare mode choice model parameters date to the early 1990's, they focused primarily on models estimated from data collected in the 1960's and early 1970's. This reflected the lack of household travel survey activity in the late 1970's and 1980's. Despite the age of the data from which these models were developed, many areas still transfer parameters from these older models, and average coefficients from these models are often referred to in determining the "correctness" of models used in urban areas today.

There are now a number of mode choice models estimated from more recently collected data, and it is appropriate to reconsider the transferability of parameters from models estimated from data that are now more than two decades old. This paper describes the results of a comparison of key level of service parameters—including in-vehicle time, out-of-vehicle time, and cost—from several models estimated from household travel survey data.

The paper is organized as follows. First, a brief discussion of the reasons for transferring mode choice model parameters is presented, followed by a discussion of some of the issues associated with transferring parameters. Next, the results of a comparison of mode choice model parameters estimated in eleven U.S. urban areas from original local data are presented. The level of service variable coefficients are compared among the different urban areas and to the coefficients from a "composite" model. The "composite" model has coefficients that are based on several models estimated from data collected between 1960 and 1984 and has been used as the basis of transferred coefficients in some U.S. urban area model choice models. The effects of using coefficients from the various models are compared using a simple hypothetical example. Finally, our conclusions regarding the use of transferred mode choice model parameters are presented.

Reasons for Transferring Mode Choice Model Parameters

On the surface, it would appear that a mode choice model based on local data should be far preferable to one based on data from another area. However, there are several reasons why many areas have chosen to transfer model parameters from another area. These include the following:

Collecting local survey data is expensive**.** The data needed to estimate logit mode choice models come from household travel surveys. These surveys can be very expensive and time consuming to conduct. In the largest urban areas—those with the highest transit mode shares—several thousand households would have to be surveyed to obtain enough observations of transit trips to develop statistically significant parameter estimates for even a simple binary mode choice model. With such surveys costing upwards of $100 per household, this can be an extremely expensive proposition. With no clear non-anecdotal evidence that the basis for travel behavior decisions differs greatly among residents of different urban areas, it is difficult in many areas to justify allocating resources for such a data collection effort when the alternative of transferring model parameters is much cheaper.

Lack of local survey data on transit usage**.** In all but the largest urban areas in the U.S., transit shares for all trips are around one percent or less. The sampling frame for a household travel survey is likely to have an even lower share since many of the market segments that are likely to have higher transit usage, such as lower income households or those without telephones, are likely to be undersampled. This means that a household travel survey is unlikely to have enough transit trips with which a mode choice model can be estimated, especially considering that generally separate models are estimated for three or more trip purposes.

Consider the following example: Say the transit share for non-home based trips in an urban area is one percent, and that the average household makes 2.5 non-home based trips. To obtain even 100 non-home based transit trip observations in the data set, 4000 households would have to be surveyed, assuming random selection. This is a far higher number of households than are needed to statistically significantly estimate parameters for other model components such as trip generation and trip distribution. If one wished to include transit submodes (e.g., bus vs. rail, access modes), the number would dramatically increase.

There are ways to increase the number of transit observations in a model estimation data set, including oversampling potential transit users in the household survey or conducting a separate survey of transit users such as an on-board transit survey. However, these methods will add to the cost of the survey effort.

Ensuring reasonable parameters and relationships**.** An advantage to transferring model parameters is that one can choose a set of parameters that have been validated and exhibit reasonable sensitivities to changes in variable values and reasonable implied tradeoffs among variables. There is no guarantee that in estimating model parameters from a new data set, there will not be unreasonable sensitivities (e.g., the implied value of time is too low or too high).

Problems with Transferring Parameters

There are several potential problems associated with transferring model parameters from one area to another. These include the following:

Different conditions in other areas**.** When transferring model parameters from another area, there is an implied assumption that travelers in the area to which the parameters are transferred exhibit the same reactions to changes in level of service attributes, such as travel time and cost as travelers in the other area. There is anecdotal evidence, but no conclusive proof that travelers in different urban areas have different reactions. There have been studies showing that sensitivity to cost among travelers varies by income, and average income levels certainly vary among urban areas. One might expect that travelers might become more accustomed to congestion, and therefore less sensitive to travel time increases, in larger, denser urban areas, but there have been no definitive studies to prove this.

Changes over time**.** There have not been any studies of how significantly travelers' sensitivities to level of service parameters change over time. However, cost parameters in mode choice models are estimated with data from a household travel survey conducted at a single point in time. If the survey data for the area from which parameters are transferred were not collected in the base year for the model to which the parameters are transferred, there must be some type of adjustment in the cost parameter to account for inflation. “Composite” model parameters based on models estimated in several areas must take into account the different years in which the data were collected in these areas.

Uncertainty about the original source model**.** Many if not most original mode choice models include variables other than level of service variables. These may include auto ownership, development density, income, trip length, and geographic “dummy” variables. These variables are correlated to some extent with the level of service variables and therefore can affect the parameter estimates. However, the effects of other variables are rarely considered when level of service parameters are transferred from one area to another.

Comparison of Parameters from Models Developed with Locally Collected Data

To compare the mode choice model parameters estimated using original local survey data sets, documentation was obtained for mode choice models estimated using locally collected data for eleven different urban areas in the U.S. (Note that the model parameters presented in this paper do not necessarily reflect the “official” or current models being used in these MPOs.) The eleven areas selected are not intended to be representative of U.S. urban areas; rather, they included urban areas for which complete documentation of the mode choice model estimation procedure, including the data source, could be obtained. Several of the model parameters were documented in a report by the Institute of Transportation Engineers [6].

The models for the eleven urban areas are presented in Tables 1, 2, and 3 for home based work, home based non-work, and non-home based trips respectively. (Unless otherwise noted, the models for each area were estimated for these three trip purposes; if other purposes were used, the purposes shown in Tables 1, 2, and 3 are indicated.) While there is not enough space here to document all of the assumptions used in the estimation of these models, it should be noted that there were significant assumptions associated with all of them, including in some cases additional non-level of service variables and fixing of coefficients or relationships between coefficients to pre-determined values. The models are described below (the year local survey data were collected is indicated).

- **Dallas** (1984) - Multinomial logit models with alternatives for transit (walk access and auto access for home based trips) and auto with several occupancy levels (1 through 3+ for home based work, 1 through 2+ for home based non-work and non-home based) were estimated. Models were originally estimated using 1984 home interview and on-board transit survey data. [6]

- **Denver** (1985) - Multinomial logit models with alternatives for transit (walk access and auto access for home based work trips) and auto (with occupancy levels 1 through 3+ for home based work trips) were estimated. Models were originally estimated using 1985 home interview and a 1986 on-board transit survey data. [6]

- **Detroit** (1965) - Multinomial logit models with alternatives for transit and auto with several occupancy levels (1 through 4+ for home based work, 1 through 5+ for home based non-work and non-home based) were estimated. Models were originally estimated using 1965 survey data and recalibrated to match 1980 transit survey data. [1]

- **Los Angeles** (1991) - Multinomial logit models were estimated from household and transit on-board survey data for five trip purposes: home based work, home based school, home based other, work based other, and non-work based other. The home based other coefficients are reported in Table 2; the non-work based other coefficients are reported in Table 3. Modes include the following:

  - **Home based work:** Non-motorized, drive alone, drive 2 person, drive 3 person, auto passenger, local transit-walk access, local transit-auto access, express transit-walk access, express transit-auto access.

  - **Home based other** - Drive alone, drive 2 person, drive 3 person, auto passenger, local transit-walk access, local transit-auto access, express transit-walk access, express transit-auto access.

  - **Non-home based:** Non-motorized, drive alone, drive 2 person, drive 3 person, auto passenger, transit. [3]

- **Milwaukee** (1991) - Multinomial logit models (drive alone, carpool, transit) were estimated for the three trip purposes. [9]

- **Philadelphia** (1986) - Nested logit models were estimated for home-based work and home-based non-work trips; a multinomial logit model was estimated for non-home based trips. Modal alternatives include drive alone, 2-person carpool, 3-person carpool, regional (commuter) rail, subway/elevated, and bus. Access modes were also modeled for transit modes. [4]

- **Pittsburgh** (1978) - Multinomial logit models were estimated with alternatives for transit and auto, with a stratification to estimate transit shares by access mode (walk or auto). Models were originally estimated using 1978 survey data and recalibrated in the late 1980's. [6]

- **Portland** (1985) - A multinomial logit model (drive alone, carpool, transit-walk access, and transit-auto access) was estimated for home based work trips. Binomial (auto/transit) logit models were estimated for home based other, work based other, and non-work based other trips. School and college trips are not included in the home based other category. The non-work based other coefficients are reported in Table 3, but the work based other coefficients are close to these. [8]

- **Sacramento** (1991) - A nested logit model was developed for home based work trips, and multinomial logit models were developed for home based school, home based other, and non-home based trips. The home based other coefficients are reported in Table 2. Modes include auto, transit-auto access, transit-walk access, walk, and bicycle; for home based work trips, three auto modes representing occupancy levels of 1, 2, and 3+ were considered. [5]

- **St. Louis** (1965) - Multinomial logit models with alternatives for auto, carpool, and transit were estimated. Models were originally estimated using 1965 survey data. [6]

- **Tucson** (1993) - Multinomial logit models were developed for four purposes: home based work, home based school, home based other, and non-home based. Modes include drive alone, carpool, transit, walk, and bicycle. [7]

In addition, a "composite model" was included in the comparisons. These parameters were compiled by Schultz and have been documented in the *Short Term Travel Model Improvements* report [2]. They were based on models estimated from data collected in U.S. urban areas from 1960 to 1984 and are intended to provide a basis for transferred parameters. These parameters are "reasonable" in terms of both the implied sensitivities to various level of service variables and the interrelationships (i.e., tradeoffs) among the variables. Mode choice model parameters are often compared to parameters such as these in model validation reports.

The travel time parameter comparisons for home based work trips shown in Table 1 demonstrate consistency among the eleven models, but the highest parameters for each variable are approximately double the lowest. The averages are very close to the parameters for the composite model. The cost parameters show somewhat less consistency. The composite model parameters are not that close to the averages, but it should be pointed out that most of the models force all cost parameters (auto, parking, and transit) to be the same. The composite model cost parameters are much more consistent with those estimated from the models where the cost parameters were not forced to be the same.

The parameters for home based non-work and non-home based trips, as shown in Tables 2 and 3, exhibit much more inconsistency with one another. This is not surprising given that there were likely fewer observations of transit trips in the model estimation data sets for these trip purposes, and one would expect that the statistical significance of the parameter estimates for these purposes is lower than for work trips. The composite model coefficients are generally lower than the averages of the eleven urban area models for these trip purposes, but this is in many cases due to one or two models with much higher parameter values than the averages.

Simple Example Showing the Effects of Varying Parameters

A simple example can show the effects of varying model parameters on the mode choice model results. Consider a single origin-destination pair with level of service characteristics as shown in the first column of Table 4 ("original"). Assume that there are no variables other than level of service variables that affect mode choice. The transit constant has been set so that the transit share is equal to 10% for each model.

Now assume that new transit service will be provided for another origin-destination pair as shown in the second column of Table 4 ("new"). The auto in-vehicle time and costs (exclusive of parking) are twice the values for the original O-D pair while the transit in-vehicle times and costs are 1.5 times the original. The out-of-vehicle times and parking costs are the same as for the original O-D pair. When each model, with the transit constant calibrated as described above, is applied to the new O-D pair, the mode shares vary significantly, ranging from 10.2% for the

Denver model to 19.8% for the Philadelphia model. The composite model yielded a transit share of 10.2% while using the average model parameters yielded a share of 12.2%.

This simplified example clearly shows that transferred parameters can yield significantly different results than models estimated from locally collected data, even when the models are calibrated to existing conditions. If the model from, say, Pittsburgh were transferred to St. Louis for this example, the transit share could be overestimated by over twenty percent, compared to the results of the locally estimated model. If the composite model were used, the share would be underestimated by over twenty percent.

Conclusions

Transferring mode choice model parameters is necessary when sufficient local data are unavailable. On average, parameters from transferred models seem to be reasonable, particularly for home based work trips. However, transferred parameters must be used with caution and with a complete understanding of the original model and its assumptions. The complete model, not just selected coefficients, should be transferred since variables may be correlated with one another.

While in many cases it is impossible to obtain a good locally collected survey data set for model estimation, it is important to use local data when available. Clearly, there are significant differences among the model parameters estimated for different U.S. urban areas at different times, and these differences can have significant impacts on the results when these models are applied. There is not enough evidence to say whether these differences are the result of differences in travel behavior among the areas, in the context of the data collection itself, or some combination of the two. But the fact that the differences exist suggests that the use of transferred model parameters is inferior to the use of models estimated from locally collected data when the latter are available.

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Table 1. Comparison of Home Based Work Model Parameters

Model	Year	Auto IVT (min)	Auto OVT (min)	Auto Operating Cost ($)	Parking Cost ($)	Transit IVT (min)	Transit Walk Time (min)	Transit Wait Time (min)	Transit Transfer Time (min)	Transit Cost ($)
Composite		-0.025	-0.050	-0.400	-1.200	-0.025	-0.050	-0.050	-0.050	-0.500
Dallas	**1984**	-0.030	-0.055	-0.460	-1.160	-0.030	-0.055	-0.055	-0.055	-0.460
Denver	**1985**	-0.018	-0.093	-0.350	-0.950	-0.018	-0.054	-0.028	-0.059	-0.440
Detroit	**1965**	-0.046	-0.260	-0.650	-0.650	-0.046	-0.064	-0.117	-0.038	-0.650
Los Angeles	**1991**	-0.021		-0.296	-0.296	-0.021	-0.053	-0.053	-0.053	-0.296
Milwaukee	**1991**	-0.016	-0.041	-0.450	-0.450	-0.016	-0.041	-0.041	-0.041	-0.450
Philadelphia	**1986**	-0.042		-0.260	-0.260	-0.011	-0.032	-0.051	-0.051	-0.115
Pittsburgh	**1978**	-0.047	-0.069	-2.100	-2.100	-0.047	-0.069	-0.069	-0.069	-2.100
Portland	**1985**	-0.039	-0.065	-1.353	-1.353	-0.039	-0.065	-0.040	-0.090	-1.353
Sacramento	**1991**	-0.025	-0.038	-0.279	-0.279	-0.025	-0.038	-0.038	-0.038	-0.279
St. Louis	**1965**	-0.023	-0.057	-1.170	-1.170	-0.023	-0.057	-0.057	-0.057	-1.170
Tucson	**1993**	-0.018		-0.184	-0.184	-0.018	-0.040	-0.040	-0.040	-0.184
Average		-0.029	-0.085	-0.687	-0.805	-0.027	-0.052	-0.053	-0.054	-0.682

Table 2. Comparison of Home Based Non-Work Model Parameters

		Auto IVT (min)	Auto OVT (min)	Auto Operating Cost ($)	Parking Cost ($)	Transit IVT (min) ($)	Transit Walk Time (min)	Transit Wait Time (min)	Transit Transfer Time (min)	Transit Cost ($)
Composite		-0.008	-0.020	-0.800	-2.000	-0.008	-0.020	-0.020	-0.020	-1.000
Dallas	**1984**	-0.004	-0.007	-0.230	-0.580	-0.004	-0.007	-0.007	-0.007	-0.230
Denver	**1985**	-0.012	-0.076	-1.310		-0.012	-0.076	-0.076		
Detroit	**1965**	-0.007		-9.960	-9.960	-0.007	-0.011	-0.018	-0.018	-9.960
Los Angeles	**1991**	-0.024	-0.061	-0.216	-0.216	-0.024	-0.061	-0.061	-0.061	-0.216
Milwaukee	**1991**	-0.009	-0.069	-1.330	-1.330	-0.009	-0.069	-0.069	-0.069	-1.330
Philadelphia	**1986**	-0.020		-0.100	-0.100	-0.001	-0.002	-0.002	-0.002	-0.012
Pittsburgh	**1978**	-0.017	-0.079	-1.450	-1.450	-0.017	-0.079	-0.079	-0.079	-1.450
Portland	**1985**	-0.033	-0.086	-0.399	-0.399	-0.033	-0.086	-0.086	-0.086	-0.399
Sacramento	**1991**	-0.021	-0.055	-0.557	-0.557	-0.021	-0.055	-0.055	-0.055	-0.557
St. Louis	**1965**	-0.024	-0.060	-2.430	-2.430	-0.024	-0.060	-0.060	-0.060	-2.430
Tucson	**1993**	-0.024		-0.250	-0.250	-0.024	-0.054	-0.054	-0.054	-0.250
Average		-0.020	-0.068	-1.855	-1.855	-0.018	-0.053	-0.054	-0.054	-1.845

Table 3. Comparison of Non-Home Based Model Parameters

		Auto IVT (min)	Auto OVT (min)	Auto Cost	Parking Cost ($)	Transit IVT (min) ($)	Transit Walk Time (min)	Transit Wait Time (min)	Transit Transfer Time (min)	Transit Cost ($)
Composite		-0.020	-0.050	-0.600	-1.600	-0.020	-0.050	-0.050	-0.050	-0.800
Dallas	**1984**	-0.012	-0.024	-0.440	-0.700	-0.012	-0.024	-0.024	-0.024	-0.440
Denver	**1985**	-0.013	-0.033	-1.330		-0.013	-0.033	-0.033		
Detroit	**1965**	-0.016	-0.355	-4.670	-4.670	-0.016	-0.023	-0.039	-0.039	-4.670
Los Angeles	**1991**	-0.050	-0.126	-0.453	-0.453	-0.050	-0.126	-0.126	-0.126	-0.453
Milwaukee	**1991**	-0.011	-0.074	-0.310	-0.310	-0.011	-0.074	-0.074	-0.074	-0.310
Philadelphia	**1986**	-0.004	-0.009	-0.046	-0.114	-0.007	-0.017	-0.017	-0.017	-0.086
Pittsburgh	**1978**	-0.012	-0.195	-3.050	-3.050	-0.012	-0.195	-0.195	-0.195	-3.050
Portland	**1985**		-0.127				-0.127	-0.127	-0.127	
Sacramento	**1991**	-0.035	-0.082	-1.103	-1.103	-0.035	-0.082	-0.082	-0.082	-1.103
St. Louis	**1965**	-0.023	-0.058	-2.350	-2.350	-0.023	-0.058	-0.058	-0.058	-2.350
Tucson	**1993**	-0.014		-0.151	-0.151	-0.014	-0.031	-0.031	-0.031	-0.151
Average		-0.020	-0.128	-1.517	-1.525	-0.021	-0.081	-0.083	-0.083	-1.522

Table 4. Data for Simple Example

	Original O-D Pair	**New O-D Pair**
Auto IVT (min)	20	40
Auto OVT (min)	5	5
Auto Operating Cost ($)	$1.00	$2.00
Parking Cost ($)	$1.00	$1.00
Transit IVT (min) ($)	40	60
Transit Walk Time (min)	10	10
Transit Wait Time (min)	10	10
Transit Transfer Time (min)	0	0
Transit Cost ($)	$1.50	$2.25

Table 5. Results of Example

Model	Transit Constant	Transit Share
Composite	-5.422	10.2%
Dallas	-5.625	11.1%
Denver	-5.012	10.2%
Detroit	-7.111	11.6%
Los Angeles	-3.852	10.7%
Milwaukee	-4.269	11.1%
Philadelphia	-3.856	19.8%
Pittsburgh	-10.184	15.8%
Portland	-7.817	13.5%
Sacramento	-4.153	10.6%
St. Louis	-6.612	13.0%
Tucson	-3.415	10.4%
Average	-5.743	12.3%

Forecasting Peak-and-Ride Demand in a Complex, Parking-Congested-Constrained Transit System

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Abstract

Accurately forecasting the demand for park-and-ride facilities is, perhaps, one of the more difficult tasks facing travel modelers. In travel modeling, smaller numbers are often harder to pin down than larger numbers, and the magnitude of demand for a given park-and-ride facility is modest relative to that for an entire transit line. In addition, the demand for use of a park-and-ride facility depends on the location and size of its market area, which, in turn, depends on variables such as the pattern and degree of roadway accessibility to the lot, the price and availability of parking at other stations, and the nature and location of other transit services.

Forecasting park-and-ride demand is particularly difficult in areas such as Boston where many existing park-and-ride lots fill to capacity early in the day. This implies that there is currently some amount of latent or unseen demand for parking, and it is very difficult to estimate the size of that demand. Furthermore, at-capacity lots influence travel decisions in ways that are not usually captured well in traditional models. A seemingly high-utility transit path selected by pathbuilding software for a given origin-destination pair may, in truth, be unavailable to most actual and potential transit choosers due to their inability to find a parking space at the park-and-ride lot located on that path.

Over the years, CTPS has developed several different ways of forecasting park-and-ride demand under capacity-constrained conditions. Typically, these methods depend on refining and running the regional travel model set, and then using a post-modeling technique to further refine the forecast. When a constrained parking lot undergoes an expansion, or when a new lot is built in an area of constrained parking lots, a complex set of diversions from competing lots and transit services to the new or expanded facility takes place. The regional travel model set does not trace these diversions well.

This presentation will focus on one or two of the best park-and-ride demand forecasting methods in the context of one or two recent projects done by CTPS for the Massachusetts Bay Transportation Authority (MBTA).

Simultaneous Multi-Class Multi-Mode Equilibrium Model with Nested Logit Demand Model

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Abstract

In this paper we consider a complex multi-class multi-mode network equilibrium model with a nested logit demand model structure. The model is formulated as a variational inequality problem and solved by a Gauss-Seidel block decomposition approach. The resulting algorithm makes use of computational blocks which are network equilibrium assignment, transit assignment, two dimensional balancing and matrix computations. Results obtained for the City of Santiago, Chile with 13 classes, 3 trip purposes and 11 modes are given in detail. This approach may be used in other cities which use nested logit demand functions.

Subarea Modeling with a Regional Model and CORSIM

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Abstract

Regional travel demand models have large transportation analysis zones (TAZs) and include only the most important transportation facilities. Subarea models often are developed with more detail in certain areas. However, these subarea models still are too coarse for analyzing many types of alternatives. Adding detail is hampered both by the limited capabilities of regional modeling software, and by the need to maintain consistency with the regional model.

An alternative approach was used in a subarea study in Syracuse, New York – linking the regional model with a CORSIM subarea model. CORSIM is a microscopic simulation package sponsored by the Federal Highway Administration (FHWA) that includes a very high level of detail. The combination of the regional model and CORSIM emphasizes the advantages of both tools. The regional model estimates changes in regional travel patterns that would result from major improvements, and maintains consistency with regional travel forecasts. The CORSIM subarea model supports detailed analysis of alternatives.

In the model linkage, a one-to-many correspondence was set up between the regional model TAZs and a larger number of CORSIM subarea TAZs. For each regional model simulation, the regional model trip table was expanded to calculate the subarea model trip table. Origin-destination cells for traffic passing through the subarea were determined by tracing the regional model vines (travel paths). Internal origin-destination cells were based on the regional model, subarea land use, and subarea traffic count data. The expanded trip table then was assigned to the CORSIM network using CORSIM.

Base year CORSIM subarea models were developed for morning and afternoon weekday peak hour conditions. These models exhibit a high degree of fit with traffic turning movement counts and measured travel delay. For future years, the regional model was run first, followed by CORSIM. Many types of alternatives were analyzed which could not have been modeled with regional modeling software alone. These include specific intersection improvements, signal coordination, changes in transit operations, and access strategies.

Representing Motorists’ Route Preferences In Micro-Simulation Models

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Abstract

This paper presents a methodology to account for the effect of motorists’ route preferences in simulation. The methodology is applied to the Lodge freeway corridor; an area of an on going ITS impacts study to evaluate the effectiveness of currently installed ATMS and ATIS technologies. To evaluate ITS impacts, a micro-simulation model of approximately 1700 nodes, 2900 links, 230 signals, 10 ramp meters, and 5 changeable message signs was generated to represent a 8-km by 5-km corridor.

Path-based simulation models using a shortest distance or time criterion in vehicle assignment overlook preferences motorists may maintain related to the safety, complexity, and variability of parallel paths. By overlooking these preferences, the simulation assignment of paths compared to field observations would allocate a lesser flow on the preferred route and a greater flow on non-preferred parallel facilities. This imbalance in simulation assignment due to motorists’ route preferences would weaken the reliability and accuracy of simulation results.

Motorists traversing the Lodge corridor of metropolitan Detroit are believed to have a preference for the Lodge freeway route, although alternate shorter time-based arterial paths may be available for their north-south travel needs. In this corridor study, the INTEGRATION micro-simulation model was used. INTEGRATION allows the problem of motorists’ preferences to be addressed through the provision of multiple vehicle classes. Each class can be assigned shorts-time paths based on a different, user-specified information source. One such class labeled the LP (Lodge freeway preference) class, represents the motorist population having a preference for the Lodge freeway route. The LP class is provided a ‘perceived speed profile’ as its data source upon which to base path assignment. The perceived speed profile maintains the true link speeds for all links except those comprising the arterial path(s) parallel to Lodge freeway for which there exists a bias. The true speeds of the set of links comprising non-favored paths are multiplied by a bias factor of 1.0 (indicating no bias) or less and the resultant link speeds are placed in the perceived speed profile. The perceived speed profile will provide the LP class with a travel time on the non-favored arterial links greater than observed in the field. Thus, the LP class vehicle assignment will favor the freeway path rather than the perceived slower arterial path(s). The bias factor is adjusted iteratively until the distribution of flow between parallel freeway and arterial facilities in simulation is comparable within a specified threshold to that observed through field data. Through this iterative process, freeway bias is represented in simulation. Additionally, the bias factor is an indicator of the severity of motorists’ preference for the freeway facility.

Application of The INTEGRATION Model to the Interstate 80 Major Investment Study

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Abstract

The objective of this paper is two-fold. First, the paper demonstrates the advantages of applying INTEGRATION, a microscopic simulation model, as opposed to conventional traffic analysis tools for a subarea or freeway corridor Major Investment Study(MIS). Second, the paper explores how to construct, calibrate, and use the calibrated model for a MIS traffic analysis.

The paper demonstrates that INTEGRATION is a powerful tool for use in Major Investment Studies. Many alternatives needed to be evaluated for a MIS, including, HOV facility, Advanced Traveler Information System (ATIS), and ramp metering, in addition to the improvements on geometric conditions. These alternatives required an analysis of the entire corridor at one time. The analysis, however, needed to be microscopic enough so that turning movement volumes at the major intersections could be estimated. Therefore, the requirements of a MIS traffic analysis tool are the model must be capable of (a) modeling O-D demand tables, i.e. assigning demand trips for a specific time period, (b) modeling dynamic traffic routing, (c) modeling the dynamic interaction of freeway/arterial facilities, and (d) providing all the measures of effectiveness for traffic analysis.

The INTEGRATION model is a combined traffic simulation and assignment model that simulates the movement of individual vehicles using car-following and lane-changing logic and provides for dynamic assignment of multiple vehicle classes. In addition to the abilities of performing conventional traffic analysis such as LOS and queue analysis in a detailed microscopic simulation level for the integrated freeway and surface street network, the static and dynamic assignment function of INTEGRATION also makes it possible to (1) obtain the turning movement volumes at the major intersections for peak hours for different alternatives and (2) provide a tool for the simulation of ATIS (VMS) and ramp metering alternatives.

The process of performing INTEGRATION analysis, like all other models, involved data collection, network coding and calibration, and model application. The paper will provide lessons learned on how to determine the data collection needs, network size and accuracy level of model calibration for applying INTEGRATION to a freeway corridor MIS or similar type of study. The paper concludes that INTEGRATION is a powerful tool for use in freeway corridor or subarea transportation improvement and traffic management studies. INTEGRATION provides the means for the combination of peak hour traffic volume estimation and systematic traffic impact analysis for various types of alternatives. It is also quite useful when an analysis of the transportation improvement impacts between freeway and surface streets is necessary.

Comparison of Partial and Full Cloverleaf Interchange Operations Using the CORSIM Microsimulation Model

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Abstract

This paper describes the results of a recent and unique comparison of the traffic operations of an existing full cloverleaf interchange with that of the popular partial cloverleaf interchange configuration. This evaluation was conducted for the Sunrise Boulevard/U.S. Highway 50 interchange in Sacramento, California. The evaluation was necessary to determine if replacement of the existing full cloverleaf interchange with a partial cloverleaf configuration would improve peak hour traffic operations, which are heavily congested and affect mainline U.S. 50 operations. Local, regional, and Caltrans support for interchange funding in the 1998 State Transportation Improvement Program (STIP) was partially dependent on the analysis results given that the interchange project was competing with other important regional projects.

Given that this evaluation had to contain a high level of confidence, CORSIM was selected as the key analysis tool. CORSIM is the latest micro-simulation model to be released by the Federal Highway Administration (FHWA) and for the first time combines arterial (TRAF-NETSIM) and freeway (FRESIM) simulation models. CORSIM is one of the only analysis tools available to traffic engineers that allows all of the individual components of the arterial and freeway system at an interchange to be analyzed and simulated as an entire system. As a result, the model was used to answer a long-standing question about the performance of a full versus partial cloverleaf interchange.

Key findings of the analysis are related to the amount of traffic served by each interchange configuration and how the arterial and freeway systems operated both individually and as a system. Interestingly, the partial cloverleaf design accommodates more traffic than the full cloverleaf configuration and also improves the ability to control off-ramp and arterial traffic flows.

Introduction

The U.S. 50/Sunrise Boulevard interchange is a full-cloverleaf configuration (i.e., Caltrans type L-10) with loop ramps and diagonal ramps in all four quadrants. Because of the full cloverleaf configuration, weaving movements occur between the loop ramps on the Sunrise Boulevard overcrossing and on the collector/distributor ramp facilities that are physically separated from the mainline. All ramps are single-lane ramps. The westbound on-ramps add a lane to U.S. 50, while the eastbound off-ramp drops a mainline lane. The proposed project includes converting the current full cloverleaf interchange configuration (Caltrans type L-10) to a partial cloverleaf configuration (Caltrans type L-9) and adding ramp metering in both directions on U.S. 50. Figure 1 compares the existing interchange configuration and the proposed project.

The existing U.S. 50/Sunrise Boulevard interchange experiences substantial morning and evening peak period congestion. Observations of existing traffic operating conditions at the interchange revealed that the interchange configuration contributes to congestion because of the capacity constraints associated with certain movements such as weaving between successive loop on- and off-ramps. Since peak hour operations of the freeway and arterial can both be described as level of service F, the analysis of traffic operations for the purpose of comparing performance between interchange configurations lead to the decision that CORSIM was the most appropriate analysis tool.

The remainder of this paper describes how the model was developed and calibrated and how the model was applied to generate accurate analysis results related specifically to the questions and concerns of Caltrans.

Model Development

Development of the CORSIM model required detailed geometrics that extended beyond the immediate interchange area. The limits of the network extend from just south of Folsom Boulevard and just north of Coloma Road on Sunrise Boulevard and approximately one mile west and two miles east of Sunrise Boulevard on U.S. 50 (see Figure 1). The existing geometrics were coded into the CORSIM model along with existing traffic count data. Before using the model for any analysis, a detailed calibration effort was conducted to ensure that the model could accurately replicate existing volumes, queuing, and speeds.

The CORSIM model was calibrated to 1997 a.m. and p.m. peak hour conditions for the roadway network shown in Figure 1. In general, the calibration consisted of adjusting the model's traffic operational characteristics until the following criteria were met:

- Model traffic volumes matched existing traffic counts for Sunrise Boulevard and U.S. 50;

- Model speeds for U.S. 50 matched observed conditions using data from the Caltrans tachograph results;

- Model estimated queue lengths at intersections and ramps matched existing queues observed in the field; and

- Visual simulation matched observed bottleneck locations at the weaving locations between loop ramps.

One challenge in calibration related to the maximum saturation flowrates for arterials in the CORSIM model. Some of the existing traffic counts in the Sunrise Boulevard corridor showed saturation flowrates as high as 2,000 vehicles per hour per lane. An exact match of the field-measured saturation flowrates was not possible given the limitations in the level of adjustment that the CORSIM model allows to the ideal saturation flowrate of 1,900 vehicles per hour per lane. However, the model was able to generate saturation flowrates in excess of 1,950 vehicles per hour per lane resulting in an accurate match of existing traffic volumes.

Analysis Results

Output from the CORSIM model generates several measures of effectiveness (MOEs) that can be used to evaluate the relative merits of the proposed project in relation to the existing configuration. Key MOEs that were considered in the analysis included:

- Total Trips Served;
- Average Travel Speed;
- Vehicle Miles Traveled;
- Vehicle Hours of Delay; and
- Maximum Queue Lengths for on- and off-ramps.

Separate comparisons were prepared for U.S. 50, Sunrise Boulevard, and the entire system for each applicable MOE. Table 1 contains the comparison of system-wide operations under 2005 and 2015 conditions. Similar information is provided in Table 2 for the U.S. 50 mainline. Given the page limit for this paper, the arterial summary could not be included.

The MOEs produced by the CORSIM model were very useful in the evaluation of the two interchange configurations. This was particularly true for traffic operations on U.S. 50 and Sunrise Boulevard since existing congestion results in LOS F conditions for more than one hour during both the morning and evening peak periods. Without information such as vehicle hours of delay and average travel speed, the comparison of mainline freeway and arterial operations would have been limited to a comparison of LOS F conditions with or without the project.

It should also be pointed out that the CORSIM model provides numerous other MOEs and that the ones selected for this study were in direct response to concerns and questions from Caltrans and Sacramento County staff. This is important for future CORSIM users to understand because few other analysis tools have the flexibility to provide both traditional (i.e., High Capacity Manual) and user-defined operational results.

Key Findings

The purpose of this study was to evaluate the traffic operational impacts of converting the existing U.S. 50/Sunrise Boulevard interchange from a full to partial cloverleaf configuration. The use of CORSIM was instrumental in establishing that the conversion would provide substantial traffic operational improvements as highlighted below.

- ***Visual confirmation of calibration results.*** The CORSIM model was calibrated to match existing queue lengths and saturation flow rates. Visual simulation to confirm that model queue lengths matched existing conditions established a high-degree of confidence in the CORSIM analysis results for all scenarios.

- ***Analysis of unique design features.*** The CORSIM MOEs and visual simulation aided in measuring the operation of existing interchange features such as collector-distributor road weaving. For the proposed project, CORSIM model provided detailed analysis results regarding the operation of the proposed triple left-turn lanes for the eastbound off-ramp and the operation of ramp meters and HOV-bypass lanes for on-ramps.

- ***Visual simulation of "side-by-side" interchange operations.*** The ability to observe the full and partial cloverleaf interchanges operating side-by-side for the same time period under the same travel demand clearly demonstrated the operational benefits of the partial cloverleaf interchange design.

- ***Effective communication of analysis results to <u>all</u> interested persons.*** Visual simulation was an effective communication tool for technical staff, decision makers, and the layperson.

Based on the CORSIM analysis results, the study was able to effectively demonstrate that the partial cloverleaf interchange configuration would improve system-wide traffic operations in the interchange corridor. It would increase average travel speeds and reduce delay and queuing, and increase the total number of vehicles served in nearly all cases.

TABLE 1 **COMPARISON OF SYSTEM-WIDE OPERATIONS - 2005 AND 2015 CONDITIONS**				
Measure of Effectiveness	Existing Interchange[1]		Proposed L-9 Interchange[2]	
	A.M.	P.M.	A.M.	P.M.
Year 2005 Conditions[3]				
Average Travel Speed (mph)	22	27	33	29
Vehicle Miles Traveled	48,950	52,220	51,210	53,910
Vehicle Hours of Delay	970	580	500	620
Year 2015 Conditions[3]				
Average Travel Speed (mph)	20	21	26	25
Vehicle Miles Traveled	55,040	55,550	57,470	56,740
Vehicle Hours of Delay	1,210	1,160	960	990

Notes: [1] Does not include ramp metering for on-ramps.
[2] Includes ramp metering for all on-ramps.
[3] All 2005 and 2015 scenarios use constrained traffic volumes on U.S. 50.

TABLE 2 **COMPARISON OF U.S. 50 MAINLINE OPERATIONS - 2005 AND 2015 CONDITIONS**				
Measure of Effectiveness	Existing Interchange[1]		Proposed L-9 Interchange[2]	
	A.M.	P.M.	A.M.	P.M.
Year 2005 Conditions				
Average Travel Speed (mph)	25	29	47	36
Vehicle Miles Traveled	29,860	29,360	31,740	31,110
Vehicle Hours of Delay	380	190	90	190
Year 2015 Conditions				
Average Travel Speed (mph)	23	33[3]	37	45[3]
Vehicle Miles Traveled	33,490	30,900[3]	35,600	31,680[3]
Vehicle Hours of Delay	490	130[3]	240	60[3]

Notes: [1] Does not include ramp metering for on-ramps.
[2] Includes ramp metering for all on-ramps.
[3] Improvement or increase over 2005 conditions is due to the use of constrained traffic volumes on U.S. 50.

Calibrating CORSIM Applications and Networks with Vehicle Detector Parameters

Katherine Haire and Maureen Paz de Araujo, *Daniel, Mann, Johnson & Mendenhall, Inc.*

Abstract

The purpose of this paper is to identify the threshold criteria that will guide the CORSIM user in the selection of link detector parameters to the level of analysis being conducted. Presence detectors are placed on freeways to determine the operational performance of links within a specified network. Link operational performance may be quantified based on specific criteria extracted from detectors. Transportation planners and traffic engineers can analyze detector data to correctly prioritize and justify the need for roadway enhancements and to calibrate CORSIM networks. The performance characteristics identified for a roadway link are a direct result of the presence detector output.

To gain freeway link specific speed data as output from CORSIM, link detector locations and type parameters are coded within the FRESIM network. CORSIM allows three types of detectors to be modeled: Doppler Radar, short loop, and coupled pairs of short loops. Selection of the CORSIM detector parameters appropriate for the application is determined by the needs of the user. Selection of the detector will reflect the actual detector type currently used on the representative facility. The focus of the analysis was based on the two most frequently used detector types: the single loop and coupled pair of short loops.

Applications of CORSIM were conducted on a variety of freeway systems under varying geometric conditions, using both single loop and coupled pair of single loop detector parameters. Comparison of the two specific link CORSIM data output indicated consistent results for vehicle volumes, headway and occupancy. However, the speeds identified through the detector zone varied greatly between the two detector types. These variations will alter resulting speed output.

CORSIM uses traffic flow equations to calculate speeds through the detector zones differently for each detector type. The single loop detector equations factor an average vehicle length to determine the speed over the detector. The coupled pair eliminates the average vehicle length within the equation and calculates an individual vehicle length over the detector zone. Coupled pair loop detector speed is based on the distance between detectors; headway and actual individual vehicle length is then estimated.

In the field, the coupled pair provides a precise travel speed through the detector zone. This occurs due to the elimination of the estimated vehicle length utilized by the single loop detector. However, CORSIM application for links with coupled pairs requires a representative vehicle mix as an input. In cases where the simulation is applied on unknown conditions, data on the required vehicle mix may be unavailable. For this situation, the CORSIM default vehicle mix would be utilized. This may produce results as valid as the average vehicle length estimation used in the single loop detector speed case. Therefore it is vital to identify the specific network and vehicle characteristics and analysis requirements prior to using CORSIM.

Data Reconciliation for Model Calibration/Validation: The Dallas-Fort Worth Experience

Ken Cervenka, Mahmoud Ahmadi, and Gustavo Baez,
North Central Texas Council of Governments

Abstract

With one watch, you know what time it is; with two or more watches, each with a different time, perhaps you aren't as sure about what represents the truth. This is the situation we all face in the preparation of travel survey and observed data for use with travel model development. There is no such thing as perfect data, but yet, the more sophisticated we try to make our models, the greater our reliance on meaningful detailed data. This presentation will outline the approach followed by the North Central Texas Council of Governments (NCTCOG, the MPO for the Dallas-Fort Worth area) to reconcile the local data obtained from imperfect sources. Five major activities will be addressed:

1. Basic survey and observed data cleanup—the importance of finding and correcting logistical errors, and the danger of imputing missing data.
2. Comparisons among local surveys—how the travel patterns/characteristics obtained from the 1996 household survey compare with the findings from the 1994 workplace, 1994 external, and 1996 transit onboard surveys, as well as the 1990 Census Journey-to-Work summaries and the 1995 Nationwide Personal Transportation Survey.
3. Comparisons with surveys conducted by other agencies in other regions.
4. Examination of the initial calibrated model results—comparison of the model-derived traffic and transit ridership volumes against observed conditions.
5. Secondary adjustments to the basic data, based on problems uncovered in activities 2-4.

Activity Five can be both difficult and controversial, for one must first determine how much of the problem is due to inaccurate demographic/network input data, inaccurate survey/observed data, or inappropriate model specifications. Only after rational explanations are obtained can additional data adjustments be made and documented.

Indiana University Travel Demand Survey By E-Mail

David A. Ripple, PhD, P.E., AICP and Vince L. Bernardin AICP,
Bernardin, Lochmueller & Associates, Inc.

Abstract

In cooperation with Indiana University, a cost-effective travel demand survey was developed and administered to university students within a one month time frame using electronic methods. The travel patterns of Bloomington (with 117,000 persons), like other university towns, are disproportionately influenced by student trip-making (36,000 students). Thus, the identification of student trip-making characteristics was considered essential in the development of a metropolitan travel model that calibrates well in the replication of actual traffic counts. Due to time, financial, logistic and institutional constraints, the traditional methods of distribution and collection of surveys (mail-out/mail-back or telephone) could not be used. The university lacked a campus mail system, but did have a student E-mail system. Thus, 5,000 students were invited to participate in the student travel survey through their E-Mail address, and 583 students completed and submitted the travel survey electronically at a web site on the IU computer network. The travel survey asked traditional questions about household characteristics associated with trip generation; included a trip log for documenting trips by mode, origin and destination and purpose for a typical day; and included a map area showing a compression of the travel zones for recording the trip ends. The results of the survey were used to develop the travel demand model for the *Bloomington Area Year 2025 Transportation Plan*.

Overview

In developing the travel demand model for the *Bloomington Area Year 2025 Transportation Plan,* a cost-effective travel demand survey was developed and administered to Indiana University (IU) students within a one-month time-frame using electronic methods with the cooperation of Indiana University and under the direction of the Bloomington Area Metropolitan Planning Organization (MPO). The travel patterns of the Bloomington Metropolitan Area (with 117,000 persons in the year 1997), like other university communities, are disproportionately influenced by student trip-making (36,000 students). Thus, the identification of student trip-making characteristics was considered essential in the development of a travel model that calibrates well in the replication of actual traffic counts. Due to time, financial, logistic and institutional constraints, the traditional methods of distribution and collection of surveys (mail-out/mail-back or telephone) could not be used. The University lacked a campus mail system, but did have a student E-mail system. Thus, 5,000 students were invited to participate in the student travel survey through their E-mail address, and 583 students completed and submitted the travel survey electronically at a web site on the IU computer network. The travel survey asked traditional questions about household characteristics associated with trip generation; included a trip log for documenting trips by mode, origin and destination and purpose for a typical day; and included a map area showing a compression of the travel zones for recording the trip ends. The results of the survey were used to identify student travel patterns and trip generation and to develop a student trip table for the travel model.

Process

On April 20, 1998, the MPO staff and their consultant met with IU staff to discuss the purpose and need for a student transportation survey, general content of the survey, options for administration of the survey, and general information on the location and number of students and employees. Because the finals' week of the Spring Semester was the week of May 3, 1998, the preliminary survey was simplified so that it could be easily completed through the IU computer network. On April 23, the revised survey was sent to the University to place on their computer network. The survey was conducted through the IU computer network for three days (May 6, 7 and 8), and the University forwarded the results of the survey via E-mail to the consultant who tabulated and evaluated the surveys.

Survey Instrumentation And Administration

The IU survey was based on a modification of the Kokomo (Indiana) Trip Log and Household Characteristics Survey from the *Indiana Modeling Reference System* (Indiana Department of Transportation; December, 1996). The modifications included a map of the Bloomington Campus showing Travel Analysis Zones (TAZs) with a consolidation of zones outside the campus, expansion of the trip log to reflect bus, bicycle and pedestrian modes as well as the automobile, and adjustment of the trip purposes and questions to reflect a university climate.

Typical travel surveys involve distribution of the survey instrument to a sample population through the U.S. Postal Service or other mail system, completion of the survey for two days of "actual" trip-making by the respondent, and return of the completed survey through the U.S. Postal Service. Because the University did not have a mail system for students, the University could not provide a mailing list (particularly for the off-campus student sample) due to policy constraints, and the Spring Semester ended May 9, the manner of distribution and collection of the survey was of paramount concern as direct mailing or a telephone survey would have been too costly.

To address the survey distribution/collection issue, the University suggested the use of their student E-mail computer system and agreed to administer the survey through their E-mail system. As virtually all students residing on and off-campus had an E-mail address, the University agreed to sample 5,000 students. This sampling avoided a lengthy University administrative process requiring faculty and student government approval of survey content and the solicitation of all students. E-mail messages were sent to 5,000 students who were instructed to go to the survey web page to complete and electronically transmit the completed survey. The electronic survey was set up so that only people receiving the E-mail notice could complete the survey and each person could only submit one completed survey from his or her E-mail address. After three days, the web site was eliminated. As an inducement to complete the survey during finals' week, the E-mail message included the announcement of a $500 reward to one survey respondent.

To encourage survey completion in a single sitting and meet web site requirements, the survey instrument had the following major features:

1. the typically separate on-campus student and off-campus student survey instruments were combined into a single instrument;

2. the trip log was reduced to one "typical" day rather than two "actual" days so that the survey could be completed in one computer session; and

3. the time of departure and time of arrival for each trip was eliminated.

The existing TAZ network of 86 internal and external zones was also collapsed to 26 zones to ease the burden of reporting trip characteristics. The seven TAZs covering the Indiana University campus were retained; the TAZs surrounding the campus outward to corporate limits of Bloomington were consolidated; and four zones were created for the balance of Monroe County outside the City of Bloomington.

Referring to Figure 1, the survey instrument consisted of two pages of questions and a collapsed traffic zone map. The first page covered student household characteristics including the traffic zone of residence, persons in the household excluding group quarters, licensed drivers, available cars, and persons employed, and asked about transportation improvements the students would like to see. The second page was a trip report log including the number of persons making the trip, the mode of travel (auto, bus, bike or foot), traffic zone at the beginning and end of the trip and seven trip purpose options ("home" to "work/class" or "any other place," "work/class" to "home" or "any other place," and "any other place" to "home," "work/class" or "any other place").

Results

Known Student Population Characteristics

Student population characteristics were determined from secondary information sources such as the U.S. Bureau of Census, the Indiana University Office of Registrar and the Indiana University Division of Residential Programs and Services. In the Fall of 1997, Indiana University had 34,937 students enrolled at the Bloomington Campus including 13,175 students living on-campus and 21,762 students living off-campus as shown in Table 1. Of the total enrollment, about 2.368 student were part of the indigenous population of Monroe County (containing the City of Bloomington) and 885 students commuted to campus from surrounding counties. Not only was information available on the type of housing on and off-campus; information was also available on the occupancy of student housing on-campus by traffic zone and on the ZIP code of students living on and off-campus. ZIP code information indicated that 13,558 students lived on-campus and 21,379 lived off-campus. This information enabled an assessment of the survey responses, and guided the expansion of the survey responses to the total student population by traffic zone for creation of a student trip table.

Student Transportation Survey Results

Sample Size. Most Indiana University students at the Bloomington Campus have an E-mail address, and off-campus students have access to a computer while on campus. Of the 5,000 students invited through the E-mail network to complete the student travel survey, a total of 583 usable surveys (or 12 percent) were completed on the web site and electronically submitted. With a total of 34,937 students enrolled at the Bloomington Campus of Indiana University in the Fall of 1997, the returned surveys represent about 1.7 percent of the total student population; however, because the number of surveys returned exceeded 500, the survey results have a high confidence level.

Location. Consistent with secondary information sources, 97.5 percent of the respondents in the Spring of 1998 resided in Monroe County. Based on the distribution of occupied student housing by traffic zone and the distribution of students by ZIP code, the survey responses for the on-campus traffic zones were expanded to yield 13,558 (39.8 percent) students residing on-campus in the Spring of 1998. Using information on off-campus enrollment, the distribution of students by ZIP code and survey responses by traffic zone, the 20,493 students living off-campus within Monroe County were assigned to traffic zones abutting the campus (within 0.5-mile of campus), the balance of the City of Bloomington (roughly within two miles of campus) and outside of the City of Bloomington (but within Monroe County) as shown in Table 2.

Household Characteristics. As shown in Table 3, the student household characteristics reveal that 60 percent of the households have more than one-person, nearly 97 percent households have drivers, and that only 18 percent of the households lack a vehicle. Nearly 53 percent of the households had full or part-time employees.

Student Travel Patterns. Table 4 summarizes the student trips by purpose, location and mode. The average number of daily trips per student was 3.9. Because nearly twenty (20) percent on the on-campus student population live, eat and go to class in the same traffic zone, the student household results in fewer trips than the typical non-student household. As expected, most student trips originate on-campus (56 percent) and most trips are destined for the campus (58 percent). For all locations and modes, the trip ends by purpose were 53.0 percent "home-based class/work," 30.8 percent "home-based other" and 16.2 percent "non-home based."

For all trips purposes and locations, the modal split is 56 percent by automobile, 11 percent by bus, 4 percent by bike and 29 percent by foot. As expected, alternatives modes to the automobile become less important as one moves away from the campus. On the other hand, the survey revealed some interesting modal characteristics associated with the Indiana University campus:

- While students living on-campus preferred to walk to and from activities on campus, they resorted to the automobile for 75 percent of their "home-based other" trips (shopping and recreation).
- A higher percent of the students living near (abutting) the campus (within 0.5 mile) use the bicycle for "home-based" trips than those living on campus.

- The bus is used primarily for “home-based class/work” trips, but is used by few students for “home-based other” and “non-home based” trips regardless of the place of residence.

Conclusions

From the Indiana University Student Travel Survey by E-mail, several conclusions can be drawn relative to survey results, problems and benefits. Of particular interest, on-campus students of the Indiana University Bloomington overwhelming favor the auto for “home-based” trips involving shopping and recreation. The survey revealed some basic problems that may be encountered in any travel survey:

- The respondents ignored directions to report the traffic zone where they parked for a trip as opposed to their final destination. To correct this error, the parking for commuting students had to be spotted by traffic zone, and off-campus student trips were shifted from the core of the campus where classes were concentrated to the commuter parking lots concentrated on the edge of campus.

- The respondents appeared to under-report return trips. Student trip making was factored up 25 percent in the travel model calibration process to better replicate actual motor vehicles volumes in and around campus.

However, these minor short-comings were far exceed by the benefits of the E-mail survey method that included:

- Cost-effectiveness. This is reflected in a survey administration cost of $2,000 or about $3.43 per completed survey and a total survey administration, tabulation and documentation cost of $15,000 or about $25.00 per survey.

- Timeliness. The survey was executed in 30 days from the date of the initial contact with the University through the administration of the survey to the tabulation of results.

- Sensitivity of the Travel Model. The survey facilitated the creation of a student trip table by purpose and by travel analysis zone for this university town and resulted in a travel demand model that performed well in and about the Indiana University campus where student travel patterns, purposes and modes are significantly different than the indigenous population of the City of Bloomington and Monroe County, Indiana.

Figure 1: Student Survey (Page 1)

INDIANA UNIVERSITY STUDENT TRANSPORTATION SURVEY

Welcome to the IU Student Transportation Survey for all students on and off campus. For the purposes of this survey, "student household" includes anyone you are living with in a dwelling unit (except your parents) and excluding anyone you live with in a group quarters such as a dormitory, fraternity, sorority or boarding house. If you live at home with your parents or in a group quarters, report only yourself; otherwise, report the trips of all persons in the dwelling unit.

1. While attending IU, do you live inside Monroe County? (a) YES ☐ (b) NO ☐
2. What is the traffic zone of your residence (refer to map for two-digit code)? ☐ ☐
3. How many persons live in your "student household"? ☐
   (Do not report fellow residents in a dormitory, fraternity, sorority or boarding house. Do not report relatives if you live with your parents.)
4. How many licensed drivers live at your "student household"? ☐
5. How many personal vehicles are normally used by members of your "student household" on a daily basis? ☐
6. How many persons are employed in your "student household"? (put number in box)
   (a) FULL-TIME ☐ (b) PART-TIME ☐ (c) NONE ☐
7. ON THE NEXT PAGE. Please report the trips for a typical class day for your "student household."

   Trips to report: Trips by you and anyone living with you as defined above.
   All trips by auto and transit (bus).
   All trips by bicycle or foot **between** traffic zones.
   Trips by bicycle or foot for different purposes (class, lunch, store) **within the same** traffic zone.
   Do not report trips between classes, to library or lab or to meals unless you go

   For traffic zones refer to the attached graphic. REPORT the TRAFFIC ZONE WHERE YOU PARK YOUR CAR or get off the bus even if your final destination is in another traffic zone.

8. What do you most want to see to improve the transportation system within your community?

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____
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Figure 1: Student Survey (Page 2)

Trip #	# of persons making trip	primary mode: auto =A transit bus = T bike = B foot = F	traffic zone # at start of trip (see map)	traffic zone # at end of trip (see map)	purpose of trip ("X" only one column for each trip)						
					From HOME to:		From CLASS/ WORK to:		From ANY OTHER PLACE to:		
					class/ work	any other place	home	any other place	home	class/ work	any other place
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											

Table 1: Student Population Characteristics by Location and Housing Type
(Fall of 1997)

Location/Housing Type	Number of Students	Percent of Students
On-Campus:		
resident halls	9,399	26.90%
university apartments	1,077	3.08%
fraternities	1,337	3.83%
sororities	1,360	3.89%
university trailers	2	0.01%
total on-campus	13,175	37.71%
Off-Campus:		
non-university apartment	11,155	31.93%
rent/own house	4,985	14.27%
commute	1,938	5.55%
live with parent or relative	817	2.34%
rooming house	172	0.49%
non-university trailer	38	0.11%
unknown	2,657	7.61%
total off-campus	21,762	62.29%
Grand Total:	34,937	100.00%

Table 2: Traffic Zone of Students Residence in Monroe County

Location	Survey Respondents	Total Students	Percent Students	Survey Expansion Factor	Estimated Total Population*
On-Campus	267	13,558	39.8%	50.779	15,460
Off-Campus					
abutting campus	155	10,596	31.1%	68.363	
balance of city	121	7,565	22.2%	62.517	
outside city	40	2,332	6.8%	58.302	
off-campus total	316	20,493	60.2%	64.851	
Total	583	34,051	100.0%	58.407	

* Includes non-students in married student housing

Table 3: Student Household Characteristics

Number	Percent of Households by Persons	Percent of Households by Drivers	Percent of Households by Vehicles
none		2.7%	17.7%
1	40.8%	40.0%	42.2%
2	28.3%	30.2%	19.2%
3	11.8%	10.0%	8.8%
4	11.3%	10.6%	8.8%
5+	7.8%	6.5%	3.3%
Total	100.0%	100.00%	100.0%

Table 4: Student Trips by Purpose, Location and Mode
(583 respondents)

Purpose	Location	Mode				
		auto	bus	bike	foot	total
Home-Based Class/Work Trips	on-campus	197	130	26	336	689
	1st tier near campus	156	40	24	82	302
	off-campus balance	181	23	3	4	211
	subtotal	534	193	53	422	1,202
Home-Based Other Trips	on-campus	258	14	9	63	344
	1st tier near campus	174	7	9	15	205
	off-campus balance	136	6	1	6	149
	subtotal	568	27	19	84	698
Non-Home-Based Trips	on-campus	80	30	16	122	248
	1st tier near campus	49	5	2	15	71
	off-campus balance	45	3	1	0	49
	subtotal	174	38	19	137	368
All Trip Purposes	on-campus	535	174	51	521	1,281
	1st tier near campus	379	52	35	112	578
	off-campus balance	362	32	5	10	409
	all locations	1,276	258	91	643	2,268

Alternative Procedures For Estimating Base Year And Future Year Employment At The Taz Level

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Abstract

Employment estimates are crucial to generating an accurate measure of trip attractions in travel demand forecasting models. While base year employment data are available through a variety of sources, reporting confidentiality and employment allocation between payroll and branch locations make the accuracy of employment estimates by traffic analysis zone (TAZ) a persistent problem in travel demand forecasting. In addition, most alternatives for the projection of future zonal data typically involve time consuming data manipulations and/or the purchase of expensive software packages with tremendous data input requirements.

This paper is based largely on analysis conducted as part of the ZDATA2 Development Process Study. The purpose of this study, funded by the Florida Department of Transportation (FDOT)/District 4 Planning Office, was to evaluate, recommend, and implement procedures for the development of socioeconomic data used to generate trip attractions within the Florida Standard Urban Transportation Model Structure (FSUTMS). FSUTMS is a formal set of modeling steps, procedures, software, file formats, and guidelines established for use in travel demand forecasting throughout the State. The subject of this study is the FSUTMS ZDATA2 file which consists of TAZ-level estimates of employment and other attraction-related socioeconomic variables.

One of the primary goals of the ZDATA2 Study was to achieve a greater level of confidence in base and future year employment estimates at the TAZ level. Key accomplishments of this study included a national survey of MPOs, literature review, model and data enhancements, evaluation of methods for converting land coverage data to employment, development of a land use forecasting model, and development of forecasts.

Study findings and recommendations were discussed at periodic meetings with a Technical Review Committee comprised of representatives from two FDOT offices and the five MPOs within the FDOT District 4 area (Ft. Lauderdale, West Palm Beach, Stuart, Fort Pierce, and Vero Beach). Procedures and software developed as part of the ZDATA2 Study are now being incorporated into model development and application studies in other areas of Florida. This research should be of interest to all transportation planners who wish to enhance the reliability of socioeconomic data used in travel demand models.

Technological Innovation In External Travel Surveys: A Critical Assessment

Johanna Zmud, PhD and Deborah Edrington, *NuStats International*; and
Preston Elliott, *Metropolitan Planning Commission of Nashville and Davidson County*

Abstract

This paper seeks to add to the growing body of literature on effective travel survey practices by assessing the implementation of a license plate survey, with automated data collection. The authors use a case study approach to conduct an empirical assessment of the implementation of a license plate survey in the Nashville metropolitan area. In the Nashville External Travel Survey, video technology and microcassette recorders were used to record license plate numbers for passenger vehicles. The data collection methods and survey outcomes are presented. Conclusions are drawn as to the utility of automated technologies for external surveys and recommendations are made for conducting external surveys in the future.

Introduction

The *Conference on Household Travel Surveys: New Concepts and Research Needs* examined the application of new technologies in the collection and analysis of travel survey data (1). New technologies were identified as computer-assisted telephone interviewing (CATI) software, geographic information systems (GIS), global positioning systems (GPS), vehicle instrumentation, cellular telephones, bar coding, laptop computers, and video and aerial photography. The application of such technologies in travel survey data collection is expected to result in more efficient data collection, improved data quality, reduced survey costs, and more flexible output products (2). This view is strongly promoted by individuals searching for a "technological fix" for the cost and response challenges associated with trying to collect larger samples and more detailed data for travel demand models. An opposing perspective, equally supported, views new technologies in travel surveys as "big brother-like" forces which will erode individual privacy and freedom.

Both views often lack a sensitivity to the constraints on technology imposed by individuals, groups, and socio-political institutions (3). These constraints often result in the "re-invention" (i.e., changes or modifications) of the technology (4). The frequent occurrence of re-invention in the technology literature confirms that the adoption of new technologies is often a very active behavior in which the adopter customizes the invention to fit his or her conditions, rather than just the passive acceptance of a standardized innovation (5). This paper examines the implementation of a new technology for external survey data collection, and the constraints imposed on the technology by individuals, groups, or institutions. It then concludes with recommendations to re-invent the technology to better serve market needs.

External surveys, also called cordon line surveys, are a special type of travel survey. External surveys involve identifying a subset of vehicles using a particular roadway and then collecting information about that trip for which that roadway is being used. The surveys commonly collect origin and destination data, as well as trip purpose, vehicle occupancy, and trip start and end times. The data are used to develop external-external and external-internal vehicle trip tables for travel demand models.

The *traditional* method to collect travel data in an external survey is to stop cars at an external station. When this method is used, drivers can either be interviewed while the vehicle is stopped or handed a survey form to be filled out and returned by mail. Recently, many state departments of transportation (DOTs) and metropolitan planning organizations (MPOs) have been reluctant to use the roadside interview method because of concerns about public safety, insurance liability, inter-agency non-cooperation, and impacts on roadway congestion.

The *technological* solution is to conduct a license plate survey in which the license plate numbers of a sample of vehicles passing an external station are recorded by video or audio recording. The license plate numbers are converted into addresses, and then survey forms are mailed to registered vehicle owners' addresses. While interest in this new technology is growing, an empirical assessment of its implementation has yet to be conducted.

This paper describes the implementation and outcomes of a license plate survey, with automated data collection, for the Nashville External Travel Survey. In this survey, video technology and microcassette recorders were used to "capture" passenger vehicle license plate numbers. The paper discusses the most prominent barriers to widespread adoption of the technology and provides recommendations for overcoming these barriers. The paper concludes with an assessment of future implementation of the technology.

Case Study Of The Nashville Area External Travel Survey

The purpose of the Nashville Area Metropolitan External Travel Study was to analyze the travel behavior of passenger vehicle travel coming into or through the five county area of Davidson, Rutherford, Sumner, Williamson, and Wilson counties. Data from the study were used by the Nashville Area Metropolitan Planning Organization and local agencies to identify transportation needs in the region and to update transportation and air quality models for the five-county area.

Sample Design

The universe of survey sites consisted of 42 external stations identified by the Tennessee Department of Transportation (TDOT). All of these stations were along the cordon lines of Davidson, Sumner, Wilson, Rutherford, and Williamson Counties. These stations have an average daily two-way traffic volume (using 1996 figures) ranging from a high of 37,363 to a low of 718. After on-site evaluation of the sites, 16 stations were selected for the study based on traffic volume, geographic distribution, and roadway type. A questionnaire completion goal by station was established at confidence and precision levels of 95%,+/-6.3% (or 250 completed responses per station) for each of the 16 station sites.

Data Collection Methodology

Automated data collection was comprised of two methods: (1) audio recording of license plate information at non-interstate highway and state road sites, and (2) video-capture of license plate information at interstate highway sites. Cost was the primary issue in determining the data collection method. Video "capture" of license plate information was quite expensive. The cost per site for video "capture" was approximately $4,500, compared to $1,400 per site for the audio recording.

Data collection at the ten highway and state road sites was done by audio recording of license plate information as vehicle traffic flowed in each direction of the roadway. Surveyors were positioned on the shoulder of the roadway and equipped with a hand-held cassette recorder for the purpose of recording the vehicle's license plate number and state (if the plate was other than a Tennessee plate). Audio recording was conducted from 10:00 am to 5:00 pm on six observation days in late 1997. Each audio tape was transcribed within one day of data capture with information from each plate entered into an electronic file which recorded the site, day, date, time period, travel direction, license plate number, and plate state.

Data collection at interstate sites was done via video technology because of the high speed of traffic which prohibited the ability of a surveyor to accurately record license plate information as well as safety concerns for positioning surveyors on the shoulder of an interstate site. At each of the six sites, four high-speed, stop-action video cameras were positioned on a nearby overpass to record the license plate numbers of traffic flowing in each direction of travel (i.e. North-South or East-West). Cameras were angled downward and zoom lens adjusted to maximize the image of the rear license plate of vehicles. Video capture was conducted between 11:00 am and 5:00 pm on six observation days in late 1997. Each video tape was reviewed within two days of data capture with information from each readable plate entered into an electronic file which recorded the site, day of week, date, time period, travel direction, license plate number, and plate state.

Each transcribed license plate number captured either by video or audio recording was assigned a sample number that was comprised of the site code, capture date, time code, and a unique number. Thus, for site 353 at I-40 East, the control number for the eighth recorded license plate would be 3539711040108. In this control number example, 353 designates the external station site location of I-40 East, 970807 designates the date of November 4, 1997 when data capture was conducted, 01 designates the time period of 10:00 AM to 12:00 PM when data capture was conducted, and 08 designates the eighth license plate to be recorded.

Upon completion of data capture activities and preparation of electronic files, data were organized by site. The files were transmitted (via e-mail, US mail, or hand delivery) to the appropriate Department of Motor Vehicles (DMV) for the purpose of obtaining the name of the individual (or corporation) the vehicle was registered to, street address, city, state and zip code. Prior to data collection, it was agreed that only license plates for the states of Tennessee, Kentucky, North Carolina, Virginia, Alabama, Georgia, Missouri, Arkansas, Florida and Mississippi would be submitted for matching purposes. Vehicles from these states comprised over 90% of all traffic at the survey sites.

Data files for the state of Tennessee were matched within one to two days. However, the matching of license plates from other states (Kentucky, North Carolina, Virginia, Alabama, Georgia, Missouri, Arkansas, Florida and Mississippi) ranged from two weeks to six weeks. This timeframe was experienced despite prior contact with the DMV's which resulted in the expectation that the information would be processed quickly.

Questionnaires were mailed to the registered vehicle owners' home addresses within 24 hours of receiving required information from state DMVs. The mailing process used a high-speed mail merge function in which names and addresses from the DMV-provided data files were merged directly onto questionnaire self-mailers.

Questionnaire

The questionnaire was a self-mailer. The non-mailer side of the form contained a short introductory text that provided the context and purpose of the study, as well as a statement about the confidential use of the data. To alleviate additional privacy concerns, the form contained the qualifier, "Due to technology limitations, some license plate numbers may be inaccurately recorded. If you have not traveled on the highway or interstate listed below, please disregard this notice."

The form used mail-merge technology to embed information captured about the vehicle on the form. For example, the first question stated: "On Thurs., 11/6/97, a vehicle (license plate number AFG862) registered in your name was recorded traveling East on I-40 East between the hours of 1:00PM and 3:00PM. Is this information correct?".[1] If no, the addressee was instructed to disregard the questionnaire. If yes, the addressee was instructed to complete and return the form. There were 11 additional questionnaire items that requested information on trip and vehicle characteristics.

Pilot Test

The data collection methods and questionnaires were pilot tested in "full-dress rehearsal" of both the audio recording and video recording techniques. License plate numbers were captured at one site for each of the two methods. The license plate numbers were matched with the Tennessee DMV only because of cost and time constraints. Questionnaires were mailed out, and returns were tracked. Data were entered, processed, and analyzed. Minor modifications were made to the questionnaire following the pilot test. The response rate, 17% overall, was lower than expected but within an acceptable range.

Survey Outcomes

A total of 26,977 license plates were "captured" at the 16 sites (see Table 3). Of these, 17,349 (64%) were matched using DMV data bases. The match rates by site ranged from a high of 95% on a state road to 38% on an interstate. Reasons for the higher match rate on the state road

[1] Based on this information, a respondent telephoned the MPO to say that the vehicle identified in the questionnaire recently had been stolen. Tennessee Department of Public Safety officials used this information to track down and retrieve the stolen vehicle.

included (1) the larger percentage of local traffic, (2) a faster turn-around of address matches through Tennessee DMV, and (3) the lower speed of vehicles which enabled a more accurate recording of license plate numbers. A total of 1,196 questionnaires were returned for a response rate of 7%. One site (Site 358 I-24 East) reached the sample size goal of 250 completed questionnaires with a total of 252. Three sites received more than 100 completed questionnaires (Site 353 I-40 East with 170 questionnaires collected; Site 339 I-24 West with 124 questionnaires collected; Site 370 I-40 West with 105 questionnaires collected) and the remaining 12 sites collected 100 or fewer responses to the study.

Analysis of Non-Response

Because the actual study response was less than expected, the researchers made telephone calls to a random sample of non-responders to try to ascertain the reason for non-response. An electronic reverse directory was used to locate telephone numbers for registered vehicle owners. Based on this activity, we were able to organize non-response into three types (ranked by prevalence).

- Mis-Identification of Registered Vehicle Owner. The state of Tennessee has over 140 different styles of specialty (vanity) license plates to commemorate various causes and organizations. There are not unique license plate numbers assigned to each type of specialty plate. This information was not communicated to the researchers prior to the survey, and in neither of the data collection methods was style of vanity plate recorded. Due to the use of duplicate numbers for Tennessee's 140+ license plate designs, matching performed by the Tennessee DMV may have provided incorrect match records for the specific vehicle surveyed. For example, the same license plate numbers could be used for the standard plate design, as well as the "fish" plate design and "horse" plate design -- thus one set of license plate numbers may be registered to three different vehicles. The DMV provided only one match per plate and there was no way to verify if the supplied name and address was for the actual vehicle surveyed. In addition, several of the specialty designs were quite ornate or had very small numbers. License plates with these designs were nearly illegible for either audio or video recording. Thus, many questionnaires were mailed to the "wrong" vehicle owner.
- Memory Decay. Individuals could not remember traveling at the survey site on the sampled day and time. The prevalence of this situation may have been exacerbated by the situation noted above. In addition, non-Tennessee Departments of Motor Vehicles required up to six weeks to match license plate records which resulted in a long delay to mail the questionnaire and limited the respondents' abilities to recall travel patterns for specific trips.
- Privacy Concerns. Individuals expressed alarm about the way in which their license plate numbers were captured without their knowledge or consent. This situation not only contributed to non-response but also to the majority of complaint phone calls from respondents to the MPO.

A fourth circumstance that contributed to non-response surfaced subsequent to the data capture. The *Daily Tennessean*, Nashville's morning paper, ran a story on the Tennessee Department of Motor Vehicle motor vehicle registration database. The article uncovered that over 100,000 records in the database were incorrect and needed to be updated. This situation was observed in the numbers of "undeliverable" questionnaires, which accounted for approximately 10 percent of the total questionnaires mailed.

Observations about Data Collection Outcomes

Response rate, notwithstanding, the study provided valuable insight into internal and external travel patterns across the five county area. The data derived from the study were applied to models developed for analysis of traffic needs assessment, and air quality measurement. If a similar study is conducted in the future, however, the following issues should be addressed to improve results.

- Trailer hitches on vehicles covered the middle letter or number of the license plate and made it impossible to accurately record complete license plate information.
- License plates on vehicles towing a trailer were not visible.
- License plates covered by road grime or dirt were not visible.
- License plates positioned in the back window of a vehicle were not visible due to glare or because they were not within the fixed focus of the video camera.
- License plates covered by a protective plastic shield were not visible due to glare.
- The microcassette recording method also faces the following challenges:
  - Traffic tended to "clump" together and "tailgate." When this happened, plates on consecutive vehicles were unreadable.
  - The audio recording of some letters in license plates was hard to distinguish when reviewing the tape such as B vs. V, M vs. N, etc.

Discussion Of The Technology Implementation

Any technology has both a hardware aspect (consisting of material or physical objects) and a software aspect (consisting of the information base for the hardware). For instance, we distinguish between computer hardware (consisting of semiconductors, electrical connections, and the metal frame to protect these electrical components) and computer software (consisting of the coded instructions that enable us to use the tool). Both the software and hardware are essential for any practical use of the computer, but because the hardware technology is more visible to the casual observer, we often think of technology mainly in hardware terms. In the Nashville case, the hardware consisted of audio and video recorders and the software consisted of the DMV databases.

In evaluating the new technology employed to conduct the study, several issues have been identified throughout this paper which impacted data quality. Some of the more prominent issues and their perceived effect on data collection are discussed below.

Hardware Issues

- Limitations in the ability to capture clear video images due to lighting resulted in a decreased ability to transcribe all recorded license plate numbers.
  The combination of the high fixed costs for video equipment and staffing and the unpredictability of weather and visibility make this issue a nearly insurmountable

challenge. MPOs, DOTs, and survey researchers should explore the simplification of the technology that will reduce its rigid fixed cost structure.

- Limitations in the ability to decipher verbal recordings due to roadway background noise resulted in decreased ability to transcribe all recorded license plate numbers.
  A future solution is the use of high quality, sound-proof headsets for the surveyors similar to those used in telephone call centers. In addition, <u>professional</u> speech training for the surveyors would be justified.

Software Issues

- Delays for matching out-of-state license plates was a major contribution to the decreased response rates realized during the study.
  The industry would benefit from a national inter-state agreement policy in which DMV databases would be compatibly structured and readily shared for narrowly defined research purposes. This policy might be FHWA-facilitated.

- Due to address records not being updated by Tennessee DMV, a significant percentage of questionnaires were returned as non-deliverable.
  Any project requiring license plate matching must begin with a critical, candid, and detailed discussion with appropriate agency personnel about the quality of data. The discussion should include a review of any on-going activities such as changes in software, data structure, etc., that could affect the accuracy of the data available. In addition, such projects would benefit from a "disaster check" license plate matching "pre-test" in which license plate numbers might be "captured" in a parking lot (i.e., from non-moving vehicles) to ensure accuracy of license plate number transcription. These license plate numbers would be sent to the appropriate agencies for matching and questionnaires mailed out. The tracking of the outcomes of this activity would enable a relatively inexpensive and quick check on data base accuracy.

- Multiple license plate designs using identical license plate numbers presented a major difficulty in the ability to send the questionnaire to the correct household.
  Every DMV has a computer catalog of license plate designs and the permissible numbers. These catalogs should be reviewed carefully to ensure that duplicate numbers do not exist among the available designs.

Conclusion

With the adoption of ISTEA, travel demand models have grown increasingly important. They are being used to make transportation policy decisions, determine how multi-million dollar infrastructure funds are allocated, and develop long-range regional transportation plans. The soundness of the information and data used to develop these travel demand models are subsequently increasing in importance. Technology offers a critical solution for the collection of massive amounts of information needed for travel demand models in a time and cost efficient manner. However, it is important that *technological solutions* are empirically assessed within the context of actual implementation so that necessary changes and modifications (i.e., re-invention) takes place. As the Nashville case verifies, the adoption of new technologies is an active behavior in which the adopter customizes the invention to fit his or her conditions, rather than just the passive acceptance of a standardized innovation.

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Table 1:
Passenger Vehicle Response Rate by Site

Site	Location	# Plates Recorded by audio/video	# Plates Matched by DMV	Match Rate	Completed Q's Received	Response Rate
365	I-65 South	2164	1142	53%	59	5%
339	I-24 West	2241	1515	68%	124	9%
342	I-65 North	2138	1027	48%	80	8%
353	I-40 East	2220	841	38%	93	11%
353/Plt	I-40 East	606	455	75%	77	18%
358	I-24 East	3807	2014	53%	252	13%
370	I-40 West	2231	1199	54%	105	9%
371	SR 46	920	801	87%	8	1%
341	SR 11/US 41	1373	1083	79%	57	6%
346	SR 31	1526	1091	71%	37	4%
366	SR 6 S/US 31 S	1426	1113	78%	75	7%
356	SR 1/US 70 SE	1024	747	73%	19	3%
335	SR 1/US 70 W	708	514	73%	28	6%
337	SR 12/Hydes Fy	580	431	74%	10	3%
337/Plt	SR 12/Hydes Fy	700	538	77%	35	7%
369	SR 100/West	1401	1042	74%	57	6%
360	SR 10/US 231	1437	1343	93%	51	4%
348	SR 52	475	453	95%	29	7%
	TOTAL	26977	17349	64%	1196	7%

Using Customer Survey Data To Monitor The Progress Of Delaware's Statewide Long-Range Transportation Plan

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Abstract

In January of 1997 the Delaware Department of Transportation adopted *Transportation and Delaware's Future*, the Statewide Long-Range Transportation Plan (Plan). The Plan represents a dramatic change in Department philosophy from one that previously focused almost solely on providing automobile capacity to one that emphasizes a multimodal approach to providing transportation facilities and services.

One of the major components of the Plan is a "tiered system" of performance measures corresponding to its goals, strategies, policies and actions. As part of an overall program of progress monitoring, individual performance measures range from those that are more general and outcome-based for the goals and strategies to those that are more specific and output-based for the policies and actions. This system of performance measures addresses almost every aspect of the Plan and requires that various types of data be collected and analyzed at different levels of detail in order to successfully monitor the Plan and make meaningful updates. While many of the performance measures utilize data that is currently collected and analyzed as part of established monitoring programs, others, such as those related to the goals of the Plan, require new data collection and monitoring efforts. The 1997 Delaware Department of Transportation Statewide Customer Satisfaction Surveys (Surveys) are examples of one such effort.

The objective of the surveys was to provide the Department with the first year's data serving as a "baseline" for customer satisfaction regarding transportation systems and services in Delaware. Completed in November of 1997, the results of the initial surveys will be compared to subsequent annual customer satisfaction surveys, forming one of the primary indices used by the Department to track progress toward meeting the goals of the Plan. This paper presents the underlying policy issues as to why the surveys were undertaken, and how they were designed and implemented to serve as an ongoing statewide data collection program that would provide the Department with annual data that could be easily compared from year to year. Overall trends in customer satisfaction levels for various systems and services will be used to refine the Plan on a periodic basis. As such, the paper illustrates the analysis methods, statistical sampling approaches, and evaluation process used in the Surveys, as well as how the Surveys relate to the overall performance monitoring and data collection requirements of the Plan.

Introduction

When the Delaware Department of Transportation (Department) adopted *Transportation and Delaware's Future*, the Statewide Long Range Transportation Plan (Plan), in January of 1997, it committed to changing how it would provide transportation facilities and services for the state.

Its focus shifted from one that relied almost solely on vehicular capacity to meet transportation needs to one that emphasized multimodal solutions. One of the key provisions of *Transportation and Delaware's Future* is its performance monitoring program, which is designed to directly reflect its tiered system of goals, strategies, policies, and actions that form the basic structure of the Plan. This program includes a range of performance measures, from those that are outcome-based for the goals and strategies to output-based measures for the policies and actions. Many of the individual performance measures use data that is currently collected while others, such as those related to the goals of the Plan, require new data collection efforts. The Statewide Customer Satisfaction Surveys (Surveys) are examples of one such effort. The Surveys were designed and are being implemented to provide the Department with the data needed to track changes in customer satisfaction with transportation facilities and services annually. The Department was and remains interested in tracking the satisfaction of its customers with the transportation system, not the Department itself. This is reflected in how the Surveys were designed and implemented.

This paper presents the underlying policy issues as to why the Surveys were undertaken, and how they were designed and implemented to serve as an ongoing data collection program that will provide the Department with annual data that can easily be compared. As such, it illustrates the analysis methods, statistical sampling approaches, and evaluation process used in the Surveys, and how they relate to the overall performance monitoring requirements of the Plan.

The Statewide Long Range Transportation Plan

In January of 1997 the Department adopted *Transportation and Delaware's Future*, and while it served as a formal response to the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, the Plan, for the most part, was an outgrowth of a statewide planning initiative.

In early 1994, Governor Thomas R. Carper activated the Cabinet Committee on State Planning Issues to make growth and development decisions that would ensure effective and coordinated planning throughout Delaware through the year 2020. The Cabinet Committee began with a visioning process to encourage every citizen to think in a long-range way and to consider what he or she wanted the state to look like in the years to come. This effort ended in 1995 with a report titled *Shaping Delaware's Future. Shaping Delaware's Future* established guiding principles and goals for how development in Delaware should take place as well as for the state's economy, infrastructure, including transportation, and quality of life. These goals and guiding principles continue to serve as the basis for the planning activities of state and county agencies. For the Department, they are reflected in its mission "to provide a safe, efficient, and environmentally sensitive transportation network that offers a variety of convenient, cost-effective mobility opportunities for people and the movement of goods," and in the goals of the Plan.

The development of the Plan was supported by two technical documents, *Technical Report #1-System Assessment* described all of the different transportation facilities and services in the state as well as documented their condition, performance and use. It also served to reveal gaps in the Department's data gathering efforts and was the basis for many of the performance measures used by the Department. *Technical Report #2- Policies and Actions* on the other hand, provided the framework under which the Department changed its focus as it continued to provide and maintain transportation facilities and services throughout the state.

Goals, Strategies, and Polices and Actions

The Plan is built around a tiered system of goals, strategies, policies, and actions that are all aimed at the Department fulfilling its mission and meeting the provisions of *Shaping Delaware's Future*. With this in mind, the Department established the three following goals that set the overall tone of the Plan and guided the development of its seven strategies, and numerous policies and actions.

(1) To provide a safe transportation system that sustains or improves 1995 levels of access and mobility.
(2) To support the state's economic well being while remaining sensitive to environmental needs and issues.
(3) To achieve efficiency in operations and investments on the transportation system.

The strategies, while still somewhat broad, describe the approaches the Department is taking to advance the goals of the Plan. The strategies are to:

(1) Direct transportation investments to support the growth management goals of local government.
(2) Better coordinate transportation and land use.
(3) Expand the number of travel choices to reduce the number of individuals driving alone.
(4) Capitalize on new technologies to increase the efficiency of the transportation system.
(5) Emphasize preservation of existing facilities as a top priority.
(6) Manage facilities and services to get the most efficient and safest use from them.
(7) Appropriately expand transportation facilities and services while supporting economic development, and respecting environmental and agricultural needs.

To implement these strategies, the Plan includes a series of policies and actions specific to each. Generally, policies speak to the systematic view under which the Department operates while actions represent the lowest programmatic level at which the Plan is being implemented or in other words, individual projects and/or programs.

Performance Monitoring And The Plan

The Plan's performance monitoring program is built around a tiered system of performance measures in much of the same way as the basic structure of the Plan is built around a tiered system of goals, strategies, policies and actions. While the association of progress monitoring and performance measurement with transportation is not new, what is somewhat unique about the approach the Department uses is how it relates to all levels of its long-range plan.

As the Department developed the Plan, it gave the issue of performance monitoring a great deal of consideration. As a result, a performance monitoring program was outlined in *Policies and Actions* and discussed in the Plan itself. *Policies and Actions* describes the program in terms of the specific measures needed to gauge progress toward the goals and strategies as well as those needed for the policies and actions. *Policies and Actions* further describes the measures as being either output or outcome-based, and in terms of the role each plays in assessing the overall performance of the Plan.

For the purposes of the performance monitoring program and defining individual measures, the Department defined output-based performance measures in terms of what it directly produces, such as roads, transit routes or sidewalks, by implementing individual policies and actions, and what it does operationally such as by plowing snow. Outcome-based performance measures, on the other hand, are viewed as those things produced as the result of multiple outputs.[1] Thus, "Plan goals would be measured by broad outcome performance measures involving new analytic efforts. Plan strategies would be measured by outcome-based performance measures developed by looking at the aggregate impact of multiple output measures. Specific policies and actions would be measured by output performance measures tracking their implementation."[2]

To further understand this important distinction, an example can be taken directly from *Policies and Actions.* To determine if the desired outcome of increasing the overall efficiency of the transportation system, including the transit and goods movement systems, the Department is looking at several specific outputs. For the transit system these include but are not limited to the number of transit passenger miles traveled, the mode share for single-occupant travel, and park and ride lot utilization. For the goods movement system, specific outputs assessed include the total tonnage of goods moved by rail and the number of restricted bridges on highways and rail lines. Individually, these measures could indicate the effectiveness of a specific policy or action such as the implementation of new or revised transit routes or changes made to the bridge management system. Taken together however, they indicate the effectiveness of the overall strategy to increase the efficiency of the transportation system.

The Role of Statewide Customer Satisfaction Surveys

As discussed earlier, one of the more unique aspects of the Department's performance monitoring program is how it relates to all levels of the Plan, in particular the goals. In this regard, the Department established three performance measures: travel time, sustainability of investments, and customer satisfaction. Although all of these measures are outcome-based and would illustrate this relationship well, customer satisfaction is presented here because it represents somewhat of an overarching performance measure for the Plan in that it embodies most, if not all, of the strategies, policies, and actions. Also, it has a much greater potential for application by a wider range of agencies and organizations.

The responsiveness of the Department, in part, is demonstrated by its ability to improve safety, reduce congestion, improve the condition and efficiency of facilities, and operate in a fiscally sound manner, among other things. Individual customers measure their satisfaction with the transportation system in terms of convenience, affordability, and predictability, and their needs will vary according to their trip purpose and mode choice. The Department must balance these needs and respond with the best transportation solution to benefit all users.[3] Customer satisfaction then, is measured by a change in the users perceptions of the adequacy of service provided according to the mode utilized. Based on the need to measure this perception, the Department undertook the development and implementation of the Surveys.

The Statewide Customer Satisfaction Surveys

In late November of 1997 the Department conducted the Surveys using the consulting firms of Lehr & Associates, Inc. to design the questionnaires, analyze the data and report the results, and Public Opinion Research, Inc. to conduct the interviews.

Delawareans throughout the state were surveyed to assess overall satisfaction across all modes of transportation used. Additionally two customer groups were surveyed: residents that currently do not use transit but live in the transit-served areas of Delaware, and goods movement businesses. These two target surveys were conducted as a means of assessing the satisfaction of specific customer groups. As a whole, the purpose of the Surveys was to establish baseline information about customer satisfaction with the transportation system in Delaware from which customer satisfaction could be measured over time.

Objectives of the Surveys

The first and largest customer group surveyed was the General Transportation Users group which was comprised of Delaware residents, aged 16 years and older. The specific information objectives of this survey were to:

(1) Determine the level of importance of various service attributes for users of each transportation mode;
(2) Determine the level of performance of various service attributes for users of each transportation mode; and,
(3) Establish the level of satisfaction attained for each modal attribute and for the mode overall.

The second customer group surveyed was the Transit-Served Market Area Non-Users group. This group was comprised of Delaware residents, aged 16 years and older, who reside in the transit-served areas of Delaware, but who had not taken transit during the month prior to the survey. This survey had similar information objectives as those for the General Transportation Users groups but was also designed to:

(1) Identify Delawareans' awareness of and familiarity with transit services; and,
(2) Identify Delawareans' use and satisfaction with different transit service communication methods.

The third customer group surveyed was the Freight and Goods Movers User Group which consisted of businesses that ship, carry or transport goods in Delaware by either truck, rail freight, air freight or via the Port of Wilmington. The specific information objectives of this survey were to:

(1) Ascertain the level of importance of various service attributes for businesses using each transportation mode;

(2) Ascertain the level of performance of various services attribute for businesses using each transportation mode; and,
(3) Ascertain the level of satisfaction attained for each attribute and for the mode overall for each transportation mode used by businesses.

Methodology

General Transportation Users
The research objectives for this customer group presented a data collection challenge in that different user groups were simultaneously interviewed (single-occupant auto users, bicyclists, pedestrians, transit riders, etc.) and a respondent could fall into one or more user groups. To meet this challenge, the questionnaire was designed to branch into a different series of questions based on the transportation modes used by the respondent in the week prior to the survey.

In the survey, respondents were asked to rate the **importance** of several modal attributes on a 7-point scale where a rating of 1 meant not at all important while a rating of 7 meant extremely important. After rating the importance of each modal attribute, respondents were then asked to rate the current **performance** of the same set of modal attributes on a 7-point scale where a rating of 1 meant poor while a rating of 7 meant excellent. Respondents were only asked to rate the attributes for each mode they used in the previous week. Different attributes were developed for each mode, including driving alone, carpooling, transit, bicycling and walking. Respondents were also asked to provide an assessment of how well the mode in question was meeting their travel needs and to provide an assessment of the overall transportation system in Delaware.

To complete the survey, 600 telephone interviews were conducted. The sample was designed as a disproportionate random probability sample by county with proportional representation by sex. Two hundred random interviews were conducted in each of the three counties in Delaware to ensure statistically reliable results at the county level. Interviews were approximately 15 minutes in duration and the response rate to the survey approximated 76%.

The research design and sample produced results that were deemed to be very accurate. There was only a 5% chance that the range of possible error in the results reported statewide would be greater than ±4.0% and ±6.9% for county level data. The completed interviews were weighted to properly reflect the state's population by county.

Transit-Served Market Area Survey
This survey involved telephone interviews with a disproportionate random probability sample of Delaware residents residing within a transit-served area of Delaware and proportional representation by gender. A total of 100 interviews were completed of residents residing within one-quarter mile of a transit route that were aged 16 years or older and that had not used transit in the month prior to the survey. The sample was split evenly by county. Interviews averaged 15 minutes in duration and the response rate to the survey approximated 76%.

Like the General Transportation Users survey, the data from this survey were weighted to adjust the sample to proportionately reflect the numbers of households by county that are "transit-served." The weights reflect 105,115 transit served households in New Castle County, 7,519 households in Kent County and 14,996 households in Sussex County. Statewide, the margin of error for a sample of 100 is approximately ± 9.8% at the 95 % confidence level. Also, respondents to this survey were asked to rate the importance and performance of modal attributes on the same 7-point scales described above. Importantly, transit service ratings were not reported in this survey, as transit users were screened from this survey effort.

Through this survey effort, the Department was interested in obtaining information from *potential* transit users. Unlike the General Transportation Users survey, respondents were also asked about their awareness of bus services, their familiarity with the statewide transit system and whether or not the respondent had used a number of different sources for transit information and how helpful they had found the source.

Shippers and Carriers

Instead of a random statewide survey of residents, this survey collected data on customer satisfaction from businesses that either ship, carry or transport goods in Delaware. The survey involved telephone interviews with a total of 100 such businesses. The sample frame for this survey was the Delaware Motor Truck Association (DMTA) member list augmented by the Department with Port of Wilmington tenants/steamship companies, and railroads. An advance letter was sent to each company from the Secretary of Transportation, informing them of the survey effort and requesting that an individual be identified as a contact for the interview. The advance letter contained a postage-paid response card, which was mailed back to the interviewing firm. A little over 100 postcards were returned and to augment this sample, the Department randomly drew 200 corporate names off of the DMTA member list, phone numbers were looked up and the list was supplied to the interviewing firms for the conduct of the interviews. The telephone interviews were conducted during business hours and the interviews were approximately 10 minutes in duration. Response to this survey was very favorable and the actual completion rate was about one out of every three numbers provided. A toll-free telephone line was maintained for callbacks and scheduled interviews with the appropriate contact, if the initial call was made at an inconvenient time.

Like the previous two surveys, businesses were asked to rate the importance and performance of attributes on the 7-point scale described above. Like the other surveys, companies were only asked to rate the attributes for each mode the business uses to ship, carry or transport goods (truck, rail, air, Port of Wilmington).

Results

First, the mean importance score and mean performance score for each mode was calculated using the ratings given based on the seven-point scale. Tables were then developed that placed the attributes in rank order for their mean score on performance and for their mean score on importance. An example of the tables developed is shown in Figure 1 and in Figure 2 for customers using transit.

Importance-performance analysis was also conducted on the 7-point scale data collected in each survey. By comparing the scores for each attribute across both dimensions, importance and performance, it was possible to separate those attributes that customers felt were very important and were less satisfied with from those attributes that were considered less important.

Importance-performance analysis is designed to take into account that not all shortfalls in service quality are of equal concern to customers. When a modal attribute that is considered to be of primary importance falls short of a desirable level of performance, that is of greater concern that when a less important modal attribute is unsatisfactory in terms of performance. Thus, projects or programs to address or improve shortfalls in a critical area (that is, projects or programs that affect a modal attribute rated as high in importance) are likely to be considered a higher priority to the public than projects that are proposed to rectify shortfalls in areas of marginal importance (that is, affecting attributes rated low in importance). A gap can be calculated between performance and importance (mean performance score minus mean importance score) for each attribute. A negative value indicates a shortfall and a positive value indicates over-achievement relative to customer perception of an attribute's importance. Gaps were calculated for each modal attribute in each survey. Figure 3 below provides an example of this analysis.

Another way of viewing the results of importance-performance analysis is in the use of quadrant analysis. Quadrant analysis can assist policy makers in service program decisions by placing the attributes along two dimensions -- the importance of the attribute to the public and the satisfaction with system performance on the provision of these services. Having these two dimensions of customer evaluation allows for the creation of four performance quadrants as can be seen in Figure 4 below. This type of analysis is more beneficial than simply using the rank order of the attributes because it defines the customer's assessment of the services by assigning them to "action quadrants". Particularly at a time when resources for services may be limited, it is useful for policy makers to have a very clear view of the specific services that need attention. For example, quadrant analysis can separate the service attributes customers feel are very important and currently not satisfied with from those that they are satisfied with. This can distinguish attributes that are in need of corrective action (attributes with low satisfaction scores) versus those that may not need any immediate action but merely require continued maintenance (attributes with high satisfaction scores). Attributes targeted for corrective action should be addressed before attributes targeted for maintenance action.

Each attribute is assigned to a quadrant based on its relative rating to all other attributes. Therefore, the intersection of the importance and performances axes is the average of the different attributes. For example, say the average of all the importance scores is 6.0. A line is drawn through the grid at 6 on the x-axis indicating the overall average importance rating. Continuing this example, say the average performance score for all attributes is 4.5, so a line is drawn on the y-axis at 4.5. Thus, the two axes intersect at the overall mean rating of 6.0 for importance and 4.5 for performance, and a grid results with four action quadrants.

The service attributes falling in Quadrant 1 have mean importance scores above the overall mean of all importance ratings and have mean performance scores that are below the overall mean of all performance ratings (thus, these attributes are above average importance and below average performance). The services or attributes that fall within this quadrant should be of the highest priority for corrective action. Services or attributes that fall within Quadrant 2 are both below average importance and below average performance. These services or attributes also need corrective action, but immediate attention is not required since the attributes are less important to the public. These items should be monitored and receive attention or investment after the more important attributes in Quadrant 1 are addressed. The attributes in Quadrant 4 are above average in satisfaction and below average in importance. Attributes in this quadrant need only maintenance action and are of the lowest priority of all the four quadrants. Items that fall within Quadrant 3 are above average in importance and above average in satisfaction. Although these services or attributes are doing well currently, they are high priority for maintenance action and should not be neglected. Attributes that fall into this quadrant are salient issues to the public and need to be followed closely. Quadrant analysis was performed on each set of modal attribute ratings in each survey. A table, such as the above, was developed for each mode rated in each of the three surveys.

It was also possible to develop an index or overall measure from the importance-performance rating data that were collected in the three survey efforts. To develop the satisfaction index, the mean scores for both importance and performance were computed for each user group. An index of customer satisfaction was then calculated by computing the ratio between the overall mean importance score and the overall mean performance score for each user (or customer) group. The higher the value of the index, the higher or greater the level of customer satisfaction with the mode. This index was used to compare customer satisfaction across the different modes in each survey. Figure 6 contains an example from this analysis using data from the General Transportation User Survey.

Lessons Learned

The data analysis yielded useful results to understand and monitor customer satisfaction with the transportation system in Delaware. However, the small samples that resulted for customers using such modes as transit and bicycle were problematic. In the General Transportation User survey for example, only 39 respondents or 7% of the sample indicated that they had used transit, and 25 respondents or 4% had indicated that they biked for some of their trips. The incidence of these modes was too low to draw reliable or definitive profiles about customer satisfaction with these modes. To improve this aspect in the next round of customer satisfaction surveys planned, a survey specifically targeted at transit riders is planned. Because the transit system in Delaware does not have a database of riders that can be used to conduct a telephone survey (for example from the sale of monthly passes) postage-paid postcards are being distributed to transit riders as they board or wait for buses. Returned postcards will constitute the sample frame for this new survey and 100 completed interviews are planned with bus riders. An improvement approach for increasing the sample of bicyclists has not yet been determined, save conducting the survey during late spring or summer months or increasing the overall sample size four-fold (to 2400 completed surveys), a rather costly alternative.

To improve the sample frame from which the Shippers and Carriers survey is drawn, the next round of customer satisfaction surveys from this customer group will be drawn not from a member list, but from the International Registration Plan (IRP) database of registered motor carriers in Delaware. This database will then be augmented by the Delaware Department of Transportation with Class I and shortline railroads, and Port of Wilmington tenants and steamship companies.

Using The Information

To this point, the paper has discussed how customer satisfaction data fits into the performance monitoring program of the Statewide Long Range Transportation Plan, and has provided background on the accompanying methodology so it can be considered for application by other agencies or organizations. There is however, an additional point to be made. That is, how the data gathered from the Surveys is being and will be used by the Department. This can be viewed in one of two ways.

First, with only one years' worth of data collected, in the short-term and to this point, the results of the Surveys have been used as a single point of measurement, and to establish a base against which data collected in future years can be compared. The results have also been used to introduce the concept of performance monitoring as the provisions of the Plan are introduced to wider audiences. Second, in the long-term the use of the data collected from the Surveys will be expanded. Beginning in 1999 the Department will produce a progress monitoring report. This report will examine progress toward meeting the goals of the Plan and implementing its strategies, and the effectiveness of individual policies and actions. The report will evolve over time as it begins with data that is currently collected and analyzed, and expands as new data collection efforts are added to reflect new projects, policies or programs. It is here that the data from the Surveys will serve its role as a key part of the performance monitoring program. The report will be produced annually to coincide with the annual update of the Department's six-year Capital Improvement Program so it can affect project selection and development. The report will further serve to support the update of the Plan that will begin late in 1999, and to support the plan updates of the two Metropolitan Planning Organizations and one other county within the state.

Conclusions

By including a performance monitoring program in its statewide long range transportation plan, the Department has committed to adapting the way it provides transportation facilities and services to changing circumstances and the needs of its customers. The Surveys have been designed and implemented to be an integral part of that commitment and the Department will work to ensure that the Surveys remain an accurate gauge of how its customers perceive the adequacy of the service they are receiving. As such, it will remain as one of the key measures of the progress the Department is making toward achieving the goals, strategies, policies, and actions of its Plan.

References

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Figure 1 Importance Ratings – Transit Riders

	Not at all important				Extremely Important			
Attribute	1	2,3	4	5,6	7	Don't Know	Total	Mean
Safe and secure waiting areas	1.2%	5.1%	0.0%	21.6%	65.7%	6.4%	100%	6.34
Transit stops & stations with good lighting	7.5%	0.0%	0.0%	39.3%	45.6%	7.6%	100%	5.95
Seat availability	6.3%	0.0%	7.6%	19.1%	55.6%	11.4%	100%	5.94
Info on transit schedules and fares	7.6%	1.2%	0.0%	29.1%	49.3%	12.8%	100%	5.93
Good condition & clean vehicle interiors	6.3%	0.0%	0.0%	49.3%	38.0%	6.4%	100%	5.91
Courteous on-board personnel	2.6%	5.1%	2.6%	39.1%	39.2%	11.4%	100%	5.83
Frequent transit service	6.3%	5.1%	1.2%	31.7%	49.3%	6.4%	100%	5.81
Covered shelters & stations where I can wait	6.3%	2.4%	1.3%	41.8%	41.7%	6.4%	100%	5.79
Info on when to expect transit delays	7.5%	5.1%	0.0%	32.9%	48.2%	6.4%	100%	5.76
Bus-to-bus transfers	7.6%	1.2%	11.4%	39.2%	34.1%	6.4%	100%	5.51
Sidewalks to & from transit stations & stops	6.3%	6.3%	0.0%	48.0%	31.7%	7.7%	100%	5.46
Litter free stations and stops	7.6%	0.0%	0.0%	52.9%	33.1%	6.4%	100%	5.46
Special lanes on highways for transit vehicles	6.3%	7.7%	2.6%	55.5%	20.4%	7.6%	100%	5.25

Figure 2 Performance Ratings – Transit Riders

	Poor				Excellent			
Attribute	1	2,3	4	5,6	7	Don't Know	Total	Mean
Courteous on-board personnel	6.3%	5.1%	7.7%	40.5%	31.4%	9.1%	100%	5.47
Seat availability	6.3%	0.0%	11.4%	49.4%	23.9%	9.1%	100%	5.46
Good condition & clean vehicle interiors	11.4%	6.4%	16.4%	29.1%	27.6%	9.1%	100%	4.96
Litter free stations and stops	5.1%	6.4%	19.1%	52.9%	7.5%	9.1%	100%	4.84
Frequent transit service	5.1%	6.3%	22.9%	44.2%	12.5%	9.1%	100%	4.81
Info on transit schedules and fares	12.5%	11.5%	7.7%	36.7%	23.9%	7.7%	100%	4.81
Safe and secure waiting areas	1.2%	5.1%	0.0%	21.6%	65.7%	6.4%	100%	4.75
Sidewalks to & from transit stations & stops	10.1%	6.3%	21.6%	39.1%	13.9%	9.1%	100%	4.72
Bus to bus transfers	13.9%	1.2%	11.4%	30.1%	12.7%	30.6%	100%	4.69
Covered shelters & stations where I can wait	11.3%	12.7%	13.9%	22.8%	25.2%	14.1%	100%	4.68
Transit stops & stations with good lighting	16.4%	5.1%	22.9%	24.0%	12.5%	19.1%	100%	4.17
Info on when to expect transit delays	11.3%	16.5%	20.2%	32.9%	5.0%	14.1%	100%	4.00
Special lanes on highways for transit vehicles	30.1%	12.7%	16.5%	29.2%	1.2%	10.3%	100%	3.23

Figure 3 Importance-Performance Analysis – Transit Users

Attribute	Mean Importance Rating	Mean Performance Rating	Difference
Special lanes on highways for transit vehicles	5.25	3.23	-2.02
Transit stops & stations with good lighting	5.95	4.17	-1.78
Info on when to expect transit delays	5.76	4.00	-1.76
Safe and secure waiting areas	6.34	4.75	-1.59
Info on transit schedules and fares	5.93	4.81	-1.12
Covered shelters and stations where I can wait	5.79	4.68	-1.11
Frequent transit service	5.81	4.81	-1.00
Good condition and clean vehicle interiors	5.91	4.96	-0.95
Bus to bus transfers	5.51	4.69	-0.82
Sidewalks to and from transit stations and stops	5.46	4.72	-0.74
Litter free stations and stops	5.46	4.84	-0.62
Seat availability	5.94	5.46	-0.48
Courteous on-board personnel	5.83	5.47	-0.36

Figure 4 Importance-Performance Quadrants

<table>
<tr><th rowspan="2">Quadrants</th><th colspan="3">Importance Rating of Service Attribute</th></tr>
<tr><th></th><th>Below Average</th><th>Above Average</th></tr>
<tr><td rowspan="2">Performance Rating of Service Attribute</td><td>Above Average</td><td>(4)
Maintenance Action: Low Priority</td><td>(3)
Maintenance Action: High Priority</td></tr>
<tr><td>Below Average</td><td>(2)
Corrective Action: Low Priority</td><td>(1)
Corrective Action: High Priority</td></tr>
</table>

Figure 5 Satisfaction Index – General Transportation User Survey

Transportation User Group	Satisfaction Index
Carpool (only carpooled)	82.1
Transit riders	81.0
All motorists (carpool and SOV – highway only attributes)	80.1
All carpoolers (carpool attributes)	80.0
SOV users	79.7
SOV users that also carpool	76.0
Pedestrians	69.4
Bicyclists	60.3

Linking Land Use and Transportation in the Oregon Highway Plan

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Abstract

Balancing main street's need for accessibility with the state highway system's need for mobility is one of several key land use/transportation issues in Oregon's 1998 Highway Plan. The plan, an update of the 1991 Highway Plan, recognizes the links between land use and transportation, mobility and accessibility, and state and local interests. The plan recognizes the importance of main streets as compact, pedestrian-friendly community centers as well as the need to protect mobility for through traffic outside these centers. The Highway Plan includes policies on land use and transportation, access management, level of service standards, off-system improvements, and interjurisdictional partnerships that address these issues.

The policy on land use and transportation recognizes the roles and responsibilities of state and local government in maintaining accessibility and mobility on the state highway. It encourages the designation of a "special transportation area" (STA) where a community center straddles the state highway. The primary objective of a highway facility in an STA is to provide access to community activities, businesses and residences. Outside STAs, traffic speeds are higher and driveway access and spacing depend on highway classification. The designation of an STA is a joint state and local process involving a management plan that addresses street design, travel times, traffic impacts, and local auto and bicycle/pedestrian circulation. The policy directs the state to work with local governments to support compact development and maintain level of service standards outside of STAs.

The policies on access management and level of service standards are linked to this land use policy and to land use types. Since Oregon's resources for adding capacity are very limited, the plan emphasizes increased access management to provide safety and maintain travel speeds, with standards varying according to highway classification and urban development. The level of service standards are used to maintain consistency between desired highway performance and intensity of land use development.

The policy on state-local partnerships supports joint planning and project development to enhance the seamless qualities of the transportation system. The policy on off-system improvements supports state assistance on a local transportation system where the off-system improvement is a cost-effective way to improve the operation of the state highway system. Underlying the policies are state participation in local transportation planning and local participation in state highway corridor planning. These include land use elements.

In the development of the 1999 Oregon Highway Plan, Oregon made a conscious effort to link land use and transportation. This paper focuses on the policy content, planning process and difficulties of developing a highway plan that strongly links the two.

First, a little background and context. Oregon is located in the Pacific Northwest on the edge of the Pacific Rim. It has a population of over 3 million. Forecasts predict that the state will grow by 1.2 million people in the next 20 years, at a rate faster than the national average.

The state has four metropolitan planning organizations that account for 71 percent of the population, with 54 percent of the population in the upper Willamette Valley. The population outside the MPOs is dispersed in communities along the state highway system.

ODOT is responsible for about 7500 miles of state highways. The agency has considered its mission to enhance economic development and livability in terms of providing intercity and interstate mobility. The 1999 Highway Plan departs from this emphasis by recognizing the links between land use and transportation and the importance of accessibility within communities.

The Plan has been developed in the context of statewide land use planning goals, the Transportation Planning Rule, the Oregon Transportation Plan and the Governor's Quality Community Objectives.

In 1973 the Oregon Legislature passed SB 100 that established statewide land use planning program and goals and required all cities and counties to adopt comprehensive plans that comply with these goals.

In 1991 the Department of Land Conservation and Development, the agency that oversees implementation of the statewide goals, and the Oregon Department of Transportation (ODOT) adopted the Transportation Planning Rule. The Transportation Planning Rule links land use and transportation and state, regional and local transportation planning by requiring transportation system plans. The regional transportation system plan must be consistent with the state transportation system plan, and the local plan must be consistent with the regional plan. When state transportation facilities affect a specific location, ODOT must comply with the local comprehensive plan. The Transportation Planning Rule also requires correspondence between amendments to land use plans and planned transportation facilities. If there is not correspondence, then (1) the land use must be limited to be consistent with the planned function, capacity and performance measure of the transportation facility; or (2) the transportation plan must be amended to provide adequate facilities; or (3) the jurisdiction must alter the land use designation or densities to reduce auto demand.

ODOT is governed by a volunteer Transportation Commission whose five members are appointed by the Governor. In 1992 the Commission adopted the Oregon Transportation Plan, a 20-year multimodal plan that met ISTEA planning provisions. Its policies support multimodal accessibility to development within urban areas to achieve compact, highly livable urban areas.

More recently, Oregon's governor directed all state agencies to carry out six quality development objectives that promote compact development within urban growth boundaries and encourage mixed use development designed to encourage walking, biking and transit use. The governor told the Department of Transportation that it is a growth management agency. Within this context, ODOT developed the 1999 Oregon Highway Plan.

The plan refines the policies of the Oregon Transportation Plan by defining the policy direction and investment strategies in terms of the state highways, but it leaves project identification and selection to corridor, regional and local planning and programming processes. Development of the Highway Plan, a two-year process, involved five policy advisory committees made up of 66 representatives of regional and local governments, federal and state agencies, business and environmental organizations and user groups.

The policies were reviewed in 33 public meetings through the state, a series of six regional workshops for local officials, and more than 35 meetings of ODOT staff, governmental committees and business and service organizations. Over 300 local officials attended the regional workshops. The Transportation Commission had more than eight sessions to discuss the plan—some lasting two to three hours. In summary, there was a lot of interest and involvement in this plan.

The main themes of the Highway Plan are

- Investments consistent with state and local community priorities;
- Efficient management of the system to increase safety and extend its capacity;
- Partnerships with other agencies and local governments;
- Closer links with other transportation modes;
- Closer links between land use and transportation; and
- Balancing of mobility and accessibility; and
- The use of new techniques to improve road safety and capacity.

This paper focuses on connecting land use and transportation and balancing mobility and accessibility.

The plan links land use and transportation in five important areas:

- Land use and transportation policy,
- Highway mobility standards,
- Access management policies,
- Off-system improvement policy, and
- Consistency provisions that tie regional and local plans to the Highway Plan.

Land Use and Transportation Policy

The Land Use and Transportation Policy recognizes the shared and separate roles and responsibilities of ODOT and local governments for maintaining mobility and accessibility on the state highway system. While local governments are responsible for planning and zoning areas along the highway, ODOT is responsible for developing and maintaining the state highway system.

In line with the governor’s directive, the policy encourages development to be compact and in centers. The policy recognizes that traffic needs to slow down in community centers, but it strives to maintain mobility by managing access more actively outside these centers. The policy includes actions to work with local governments on access management and on protecting the highway function through various means.

In the planning process, we began by describing existing downtowns, business districts and community centers as Special Transportation Areas. That concept has since been broadened, and we have added two other concepts—Commercial Centers and Urban Business Areas—to better meet various stakeholder needs and describe other land uses. All designations are overlays. Local governments and ODOT have to jointly agree to the designation, and it has to be a part of the local transportation system plan and/or corridor plan.

At the heart of the policy is the recognition of Special Transportation Areas or STAs. Their primary objectives are to provide access to community activities, businesses and residences, and to accommodate pedestrian movement along and across the highway in a downtown, business district and/or community center. An STA is a designation that may be applied to a short highway segment that straddles the highway within an urban growth boundary. With certain qualifications, it may also apply to a rural unincorporated community.

The designation requires provisions for a network of local traffic, transit (where available), pedestrian and bicycle circulation. It supports direct street connections, but limits direct property access. It has mixed uses, with buildings spaced close together and located adjacent to the street and with ample sidewalks between the buildings and the highway. Traffic speeds are generally 25 miles per hour or less.

The STA designation is established through a management plan as part of a corridor plan and/or local transportation system plan. The Highway Plan does not encourage new STAs to be developed that are not currently in adopted plans.

In an attempt to encourage commercial development to cluster in centers, the Transportation Commission added the designation called "Commercial Center" to the plan. The primary objective of the state highway adjacent to a Commercial Center is to maintain through traffic mobility in accordance with its function. Commercial Centers generally have 400,000 square feet of gross leasable space. The buildings are clustered with limited access to the state highway to reduce the number of auto trips and conflicts with through traffic. They generally have a high level of regional accessibility and connections to a local road network and accommodate bicycle and pedestrian circulation. The incentive for clustering is a potential lower mobility standard at the point of highway access.

Late in the Highway Plan process, the Retail Task Force, representing retail developers and large supermarkets, got actively involved. They persuaded the Transportation Commission that there needed to be a designation that was friendlier to retail business. The result was a designation called an Urban Business Area that recognizes existing or future centers of commercial activity within urban growth boundaries on certain highways where speeds are 35 miles an hour or less. Future Urban Business Areas are to be nodes or centers. The primary management objective of the state highway is to maintain existing speeds while balancing the access needs of abutting properties with the need to move through traffic. Local street connections are encouraged, and transit, pedestrians and bicyclists are accommodated.

Figure 1 points out the location of each kind of highway segment designation.

Other Complementary Policies

Several policies complement the Land Use and Transportation Policy. The Policy on Highway Mobility Standards seeks to establish acceptable and reliable levels of mobility on the state highway system. These standards are used for identifying mobility performance expectations for planning and for evaluating the impacts of plan amendments on the state highway pursuant to the Transportation Planning Rule.

The standards are based on volume to capacity ratios and vary by land use type and speed limit. The National Highway System and Interstate Highways operate at a lower volume to capacity ratio than highways of lesser importance. Rural highways operate at a lower ratio than urban areas, and Special Transportation Areas are allowed to be congested. (See Table 1.)

The plan recognizes that the Portland metropolitan area cannot meet these performance measures, but that the area is trying to maintain or improve mobility performance by increasing the use of alternate modes, making land use changes including increasing density, and reducing transportation demand. The Portland mobility standards use a two-hour peak period and higher ratios for congestion.

ODOT is in the middle of a major effort to manage access to the highway through standards for freeway interchange placement and design, driveway and approach road spacing and design, traffic signal location, median design and spacing, and the use of turn lanes. The objective is safety, efficiency and protection of highway investment. The standards vary by highway classification and highway segment designation. Access management policies and standards are in the Highway Plan, and an administrative rule is being developed to address permitting and appeal processes.

The Highway Plan also recognizes that ODOT can make Special Transportation Areas and state highways in other areas work more effectively by assisting local governments in funding off-system improvements. The Off-System Improvements Policy begins a process to fund off-system improvements where the improvements are a cost-effective way to improve operations on the state highway system.

Difficulties in the Process

The development of these policies has not been easy. The Transportation Commissioners, for example, initiated some of the highway segment designations, but went through a long process in order to reach agreement on definitions and language. The concept of slowing down for communities on the state highway is already a reality, but some ODOT staff resist it. Local governments do not want ODOT interfering with their local planning but welcome agreements on Special Transportation Areas because they may mean more local control on the highways in their community centers. Language has been carefully crafted to meet local government concerns. Stakeholders want to loosen access measures, but that compromises highway efficiency.

We have struggled to define concepts and include language that provides a balance among various purposes but satisfies both the mobility needs of the through traveler and freight-hauler and the needs for accessibility within a community center.

When the Transportation Commission adopted the Highway Plan in March, the chairman told the ODOT staff to get on with the task of implementing the policies to see how they work. He noted that we can amend the plan later if we find the policies do not work. We know that our goal is to manage growth and our highways more effectively by linking land use and transportation and believe that the Highway Plan is a good step toward achieving the goal.

Table 1: Maximum Volume to Capacity Ratios for Peak Hour Operating Conditions Through a Planning Horizon for State Highway Sections Located Outside the Portland Metropolitan Area Urban Growth Boundary

Highway Category	Land Use Type/Speed Limits					
	Inside Urban Growth Boundary				Outside Urban Growth Boundary	
	STAs	MPO	Non-MPO outside of STAs where non-freeway speed limit <45 mph	Non-MPO where non-freeway speed limit >= 45 mph	Unincorporated Communities	Rural Lands
Interstate Highways and Statewide (NHS) Expressways	N/A	0.80	0.70	0.70	0.70	0.70
Statewide (NHS) Freight Routes	0.85	0.80	0.75	0.70	0.70	0.70
Statewide (NHS) Non-Freight Routes and Regional or District Expressways	0.90	0.85	0.80	0.75	0.75	0.70
Regional Highways	0.95	0.85	0.80	0.75	0.75	0.70
District/Local Interest Roads	0.95	0.90	0.85	0.80	0.80	0.75

Table 1 Notes:

- Interstates and Expressways shall not be identified as Special Transportation Areas (STAs).
- For the purposes of this policy, the peak hour shall be the 30th highest annual hour. This approximates weekday peak hour traffic in larger urban areas.

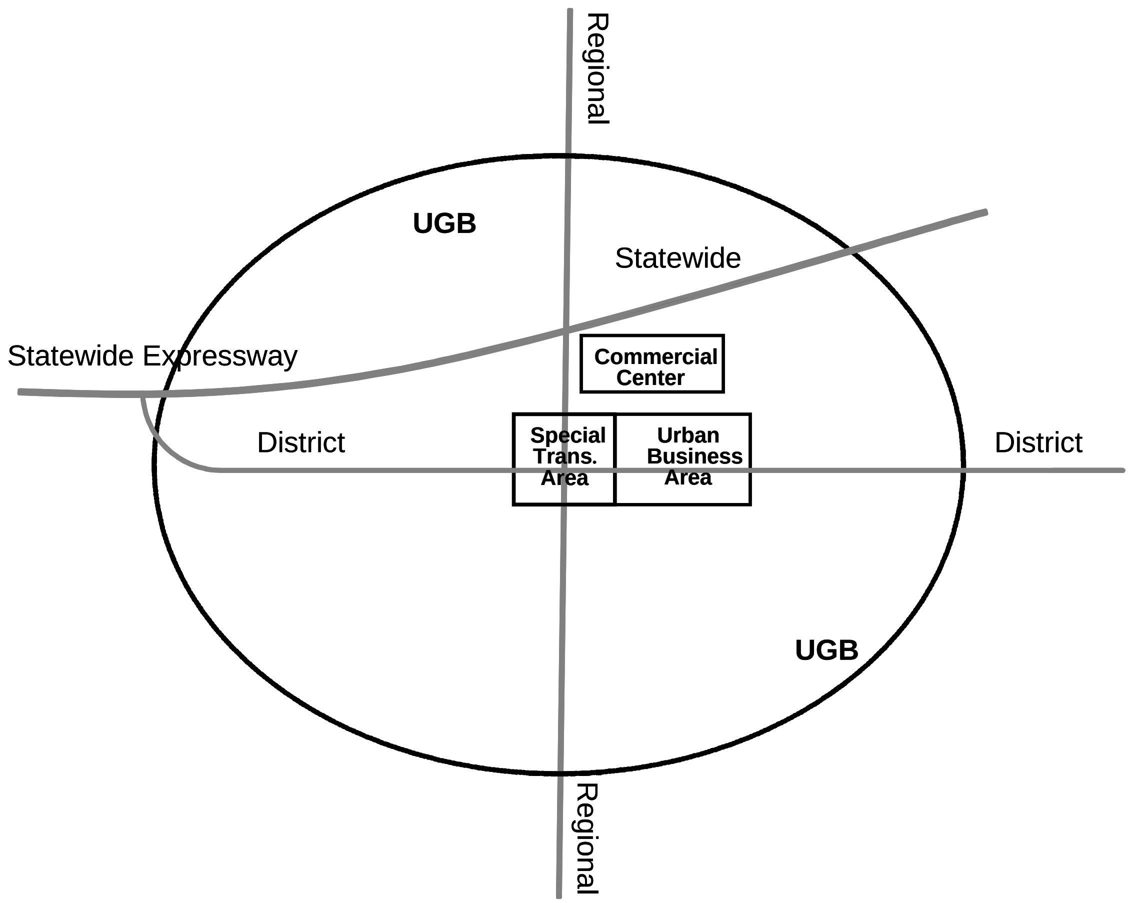

Figure 1: Highway Segment Designations

Access Management and Median Projects: Opportunities for Effective Public Involvement

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Abstract

Florida Department of Transportation has been in the forefront of access management and median projects. Access management has been shown to be an effective way to increase the safety and efficiency of our highway system. An important element of a successful access management program is the work done with the people living, working, and owning businesses along the corridors in which major improvements are planned.

In the past few years the Florida Department of Transportation has embarked on an active program to involve the public in critical decision making for access management and median projects. This program has consisted of changes to statewide procedures, working with representatives of various roadside businesses, and producing effective training for Florida Department of Transportation staff and consultants.

This presentation will highlight the lessons learned and the major points which lead to success in this program. We will also make note of those areas in which we have learned from our mistakes. We will distribute copies of Florida Department of Transportation materials related to our program to all who attend the session.

Working with Communities to Understand Noise and Vibration Issues

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Abstract

Noise is an emotional issue. Residents and abutters pressure agencies for noise mitigation because they fear physical, emotional, and structural damage from noise. Often, the mitigation is not warranted, but community pressure frequently wins out over reason and science. Agencies struggle to explain noise and often don't dare try. Instead, they assess noise problems without talking with the affected communities, the result of which is public skepticism or a downright incredulous public that disagrees vehemently with the results. Noise studies are highly technical and rely on logarithms and scientific data. It is seen as a black box , and communities often feel they don't have access to the black box and the tools being used by agencies to make mitigation decisions. However, there are effective methods agencies can use to work with communities to break down the black box and develop credible and defensible recommendations for noise and vibration mitigation. This paper describes three principles about noise studies and provides a case study example from study of a rail corridor in Massachusetts in which the agency engaged a community task force, educated them and was educated by them, and developed a credible set of recommendations that were supported by the task force.

Noise is an emotional issue. Residents and abutters pressure agencies for mitigation because they fear physical, structural, and emotional damage. Often, the mitigation demanded is not warranted, but the lack of knowledge and understanding of noise and vibration issues makes realistic and reasonable solutions impossible. As a result, political pressures often win out over scientific reason. Agencies struggle to explain noise and noise mitigation and often don't even dare try. Instead, agencies frequently assess noise problems without talking with affected communities, with less than ideal outcomes. The public excluded from the process will often reject the results of the noise study because they question the methodology and assumptions used.

Clearly, the study of noise is highly technical and obtuse to many. Noise studies involve scientific formula, logarithms, and counter-intuitive data in complicated formats. Consequently, noise assessment methods are seen as a "black box," an impenetrable model that spits out a number that determines mitigation measures and is in the exclusive domain of scientists. Communities feel they do not have access to the black box and to the tools being used to make decisions on mitigation

Working with communities on noise and vibration issues is not a lot different from working with communities to select the location of a new off-ramp or the design of a new headhouse except that one cannot see or touch noise. You can't show people a plan or a rendering of noise. You can't show people a photo of what the noise will be like. Therefore, working with communities on noise issues is more difficult than other issues. However, there are a few things that are true about noise studies:

- People who are passionate about their noise problems have an inherent ability to understand technical information.
- The perceptions and feelings of residents in impacted homes are always valid.
- If a study process is open and inclusive and people have had input into how decisions on mitigation will be made, they are more likely to accept the results.

Keys to Success in a Noise Study

In addition to these basic facts about the public's ability to engage in a technical discussion about noise, there are several keys to success in a noise study. They are:

- Selecting an excellent and versatile consultant to take the lead to increase trust and credibility. Noise consultants are highly credible; after all, a noise consultant who says there is no noise problem would be like a butcher who advises his/her customers to be vegetarians!
- Assume residents are able to understand technical information. Do not invalidate the perceptions and feelings of residents in impacted homes.
- Identify key stakeholders at the beginning to work closely and steadily with you. They will help guide the study and provide needed checks.
- Explain the goals of the study and the decision-making process at the beginning.
- Open the black box of technical data and explain the significance in real-life ways.
- Create an structured, serious, and open community participation process.
- Describe all steps in the technical process so they are understood and acceptable to the Task Force. By opening the black box and demystifying the noise assessment process, the community will be able to give meaningful input, learn, and accept the agency's mitigation decisions.

In Boston, the Massachusetts Bay Transportation Authority (MBTA) has worked with communities in a unique way on noise and vibration issues. First, the MBTA committed to analyzing noise and vibration issues on existing lines despite the fact that the Federal Transit Administration requires noise assessment only for new transit facilities, not for existing facilities. The MBTA is one of a very few transit authorities in the country that evaluates noise on existing lines and commits to mitigation. Second, the MBTA deviated from the usual approach and did not assume that this would noise study would be too complex for the community to understand. The MBTA and its consultant, Acentech Incorporated of Cambridge, Mass., allowed stakeholders to participate and relied on them to make important decisions that would in fact help decide the mitigation parameters.

The process that the MBTA undertook involved a series of comprehensive, open, and inclusive studies that involved key stakeholders and elected officials from project scoping through the proposed mitigation. Early, the MBTA gained considerable trust and credibility by pulling back somewhat from controlling all aspects of the study process. The MBTA, for a variety of reasons, is not the most trusted agency in the state. But its approach to noise and vibration studies has proved to be effective at building trust and support of the process. The MBTA had Acentech lead the study process and deal directly with the community. This process helped convince the community task force that the MBTA was not calling all the shots and potentially skewing the data. It allowed the key stakeholders access to the consultant conducting the study, thereby increasing the credibility of the study process and results.

In addition, the MBTA publicly committed to an innovative and equitable way of implementing noise mitigation that uses a Priority Index based on the benefit derived from mitigation treatment divided by its cost. Areas with proposed mitigation were rank-ordered with the greatest Priority Index at the top of the list for mitigation. This process helped reduce the ability for elected officials to push the MBTA to mitigate noise in a lower-ranked location.

Case Study: MBTA Attleboro Commuter Rail Line

In this case study, the MBTA was asked by residents to analyze noise issues along the Attleboro corridor, a rail line that carries both MBTA and Amtrak trains. The simmering noise issues had come to a head when Amtrak's Northeast Corridor Electrification Project was approved and high-speed rail was definitely going to happen.

Since the corridor extends over 45 miles from Boston to Attleboro on the Rhode Island border and contains over 2,500 potential impacted structures, prioritizing the locations for noise barriers or residential sound insulation is essential given the cost that would be involved with either method.

From the outset of the study, the MBTA made it clear that the goal was to analytically determine the most appropriate type and location of noise mitigation along the corridor and not to decide mitigation based on who shows up at meetings or asks their state representative to exert pressure. There were four key factors that made this process effective:

- The MBTA knew trust would be an issues did not control the study process, deferring to Acentech Incorporated, its consultant.
- The MBTA worked with state representatives to establish a 22-member Task Force to help guide the study and the overall process. Task Force members were empowered to approve the study process and comment on the technical analyses.
- The entire study process was outlined and reviewed at the first Task Force meeting and documented in the meeting summary. The purpose of each step and the methodology to be used was described and revised by the Task Force at the beginning of the process. The Task Force was able to buy into the study process.
- Finally, the Task Force was empowered with critical decisions that would affect the priority rankings. The fact that the MBTA was willing to let the key stakeholders make some of these decisions gave tremendous credibility to the outcome.

The overall structure and approach to the community participation process helped make the study successful. Some of the specific elements of the community participation process included:

- Regular meetings were held in a community in the study area to report on the study status, results of technical analyses, and to get input on the approach and assumptions.
- Task Force members were telephoned if they missed a meeting to keep them engaged.
- The MBTA documented the progress of the study, the technical results, and commitments in written summaries of meetings and analyses sent to all Task Force members.

- Issues raised by participants during the study were either added to the scope and addressed or deferred to other studies to follow-up.
- Task Force members were invited to observe a step in the study involving a field survey of the residential structures in the study boundaries. Inviting them to participate in this task not only helped improve the data in some cases, but also got buy-in from some of the more suspicious stakeholders that the study was being performed thoroughly and openly.

Even more important to the study's success was the way the MBTA and Acentech worked with the Task Force to explain the noise assessment procedures, data collection, noise model, and the model to calculate the Priority Index. The consultant used a variety of methods to present and explain information so that it was understandable by average Joes. It was critical that the information and data be clear--the MBTA and the consultant needed to get feedback from the Task Force and needed to know that the process and results were being accepted. The black box was opened up! Following are some of the techniques and tools used:

Explaining "What is noise?"

The consultant conducted an "acoustics tutorial" session at an early Task Force meeting that described the aspects of noise (loudness, frequency, duration), difference between day-night noise levels and event noise levels, sources of rail noise (horns, wheel squeal, station noise, etc.), and more. Acentech also worked methodically with the Task Force to make sure that all of the inputs into the mathematical noise prediction model were understood and acceptable to the Task Force.

The MBTA worked with the Task Force to establish parameters for the train data. This meant involving the Task Force in a policy decision on whether to use data from existing Amtrak trains, not trains coming on-line in three years. Also, because there are no FTA noise criterion for existing rail lines, the selection of a noise impact criterion--critical to the mitigation recommendations--was discussed and agreed to (65 dB). Another input into the model that was reviewed with the Task Force was the screening distance for the study. Coming to closure on the extent of the study area was critical to moving forward. Task Force was asked to review data assembled from photos, maps, and Geographic Information System on the location and characteristics of the homes within the study boundaries.

Hands-on Task Force Involvement

Task Force members were actively involved throughout the study process. Task Force members participated in follow-up field surveys that were done to verify results of the Geographic Information System inventory. Over 2,500 structures were inventoried. Sample noise measurements were taken at a limited number of residential locations to compare the predicted noise levels to actual measured levels. The Task Force was told in advance about the MBTA's policy that MBTA personnel are not to be informed when consultants are conducting noise tests. The policy exists to convince stakeholders that the test measurements are conducted on a typical day and that the MBTA is not slowing trains with the intent of reducing noise levels. In all, the Task Force reviewed and was in agreement with the critical inputs into the noise prediction model.

A Picture Says a Thousand Words

Making the Task Force comfortable with the concepts and ensuring that it understood the mind-boggling level of detail involved in the noise prediction model was very important. The consultant used simple diagrams and plans to explain concepts as well as to explain the level of detail of the analysis. For example, to help illustrate why this criterion was selected, Acentech used the Schultz Curve, a widely accepted empirical relationship that marries science and sociology. The Schultz Curve is a very simple, clean diagram that shows at what point people become "highly annoyed" by noise: the curve is relatively flat until the noise level reaches 65 dB. At 65 dB the curve begins to rise rapidly, suggesting this is the point at which people are annoyed and the point at which mitigation is necessary. Another example of an effective graphic was the use of a sample Geographic Information System cluster map: the consultant on several occasions brought a computer with large monitor to the Task Force meetings to demonstrate the type of data that were being collected and what the output would look like. This allowed Task Force members to look at specific data for the areas they represent. Finally, simple drawings of noise barrier design standards helped explain such concepts as "serendipitous benefits."

Flexible Study Process and Scope

The MBTA allowed the study process and scope of work to be appropriately flexible to address issues of concern to the Task Force that come up during the process. Doing so increased the credibility of the study. For example, a quick analysis of Amtrak horn-blowing policies and the effects of horns sounded passing through stations was conducted and the results presented at the following Task Force meeting. On occasion, the MBTA deemed that a peripheral issue should not bog down the noise study and recommended deferring an issue to a separate study; this was the case for a question about the impacts of diesel fumes and dust.

Analogies and Easy-to-Relate to Examples

Finding ways to explain highly technical data is a challenge. Acentech's use of analogies and real-life examples to describe and explain the technical material proved extremely effective. Analogies were valuable for communicating concepts with the Task Force. For example, when talking with someone from another country, if he/she doesn't understand what you're saying, our tendency is simply to repeat the same thing...louder. Technicians frequently have the same tendency: when someone doesn't understand a concept, the inclination is unfortunately to simply say the same thing again, hoping it sinks in. Acentech, however, was clever and used analogies to communicate concepts. When describing the results of the analysis of noise from train horns that showed that horns add 1/2 of 1 dB, the consultant noted that it's like shining a red pen light on a wall--it's visible and noticeable but doesn't add much measurable light energy to the room. It was also useful to help explain the concept of the prioritizing mitigation based on value using a real-life example. The MBTA's study looked at the benefit provided by the mitigation and the cost to implement it. This concept was explained by saying it's like a meal in a restaurant: an expensive meal is a bad value if it was not good, but a good, cheap meal can be a good value as could an expensive, good meal.

The 15-month study resulted in noise mitigation ultimately being proposed for 58 residential clusters (groups of homes that would be protected by a single noise barrier) along the Attleboro line. A priority ranking was assigned to each cluster, and the Task Force played a key role in the final determination of priority ranking. The Task Force set precedent by deciding to weigh the benefits of noise barriers higher than benefits of insulation (for the ability to enjoy one's yard). Over 300 clusters of homes were not recommended for mitigation based on the results of the study. The Task Force not only endorsed the results, but has joined with the MBTA to fight for funding for implementation.

Summary

The MBTA's success in this study of noise along the Attleboro Line is due to several key factors:

- The MBTA did not assume residents could not understand technical information. The MBTA did not invalidate perceptions and feelings of residents in impacted homes.
- Knowing there was great distrust, the MBTA selected an excellent and versatile consultant to take the lead.
- Key stakeholders were identified at the beginning to work with the MBTA. They helped guide the study and were empowered to approve the study process and comment on the technical analyses
- The goals of the study and the decision-making process were explained and accepted at the beginning.
- The "black box" of technical data was opened and explained in real-life ways
- The community participation process was structured, open, and comprehensive. The Task force was given access to the consultant team.
- The Task Force understood and basically approved of all the steps in the technical process and were acceptable to the Task Force.

By demystifying the noise assessment process, the community was able to give meaningful input, learn, and accept the agency's mitigation decisions.

Spending Resources to Maximize Participation: Using an Innovative Media Campaign as a Substitute for an Initial Public Meeting

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Abstract

MIS initial meetings are conceptual in nature and, historically, planners have had difficulty in attracting the interest of many members of the public. The abstract nature of many of these initial public meetings tends to set a negative non-participatory tone for MIS public involvement programs and tends to limit decision making to transportation "activists," or those members of the public who routinely spend large amounts of time monitoring transportation department activities.

Recently, the Kent County Road Commission in Kent County, Michigan conducted an innovative media campaign in lieu of an initial public meeting for an MIS effort to establish a needs statement. Approximately the same amount of resources, which would have been required for a public meeting, were expended on these campaigns. At the outset of the project, community and media interest was high; planners built on this enthusiasm to garner input from greater numbers of interested citizens who would typically not attend a public meeting. Innovative techniques included: billboards with an eye-catching theme; radio advertisements during peak traffic periods; media kits to all local print and broadcast media; a media conference held to announce the innovative campaign and website posting of study information.

The campaigns discussed will be of particular relevance to small- and medium-sized cities where it is easier to attract media attention, and the expenditures for billboards, radio ads, and newspaper ads can be considerably less than a comparable campaign in a larger city.

Introduction

Involving the public in decisions made about public policy, transportation or infrastructure improvements can make the difference between a project's success or failure. The participation of citizens, business interests, neighborhood groups, federal, state and local government representatives and elected officials is important in shaping public policy and implementing successful programs.

Transportation projects compete for public attention with a host of other public policy issues. Public involvement specialists strive to focus public attention on specific transportation improvements and corridors. To do so successfully, they must balance the twin goals of educating the public and eliciting public input into the transportation planning and design process. In addition, they must be sensitive to community styles and standards and use appropriate methods to capture public notice.

Among the different kinds of transportation studies conducted throughout the nation, those that impact both regional and local citizens in significant ways are unique. This paper will discuss how the effective use of media has successfully involved both regional and local citizens in the planning process of an airport access study in Kent County Michigan.

Since the perception of regional citizens is that local projects will not likely directly impact their lives, involving regional citizens in local planning discussions presents a communication challenge. Also, communicating with regional audiences can be problematic from a resource standpoint.

The need for public input early-on in some studies presents the additional challenge to gather feedback without having any defined proposals on which the public can comment. This challenge applies to both local and regional citizens.

Background

The I-96/Airport Area Access Major Investment Study (MIS) seeks to improve access from Interstate 96 to Kent County International Airport while improving circulation on roadways leading to and surrounding the airport. The access and circulation improvements will physically impact local neighborhoods and communities during and after construction, while the improvements will directly impact the access of regional citizens to the airport. The project is being conducted by the Kent County Road Commission in cooperation with the Michigan Department of Transportation and local governments near the airport.

Kent County Michigan lies in the southwest quadrant of the state of Michigan. Within the county lies the Grand Rapids metropolitan area and several bedroom communities. Total population in the region is estimated at nearly one million people. The area has experienced dramatic commercial and residential growth over the past decade.

Interstate 96 is the major east-west freeway moving people, goods and services. There are significant stretches of the interstate where no ramps exist to provide access to and egress from local areas. Kent County International Airport is located to the south of I-96 in the midst of a 14-mile stretch of interstate with only one exit to serve local citizens, employees and airport travelers.

Public Involvement Goals

The goals for involving the public in the I-96/Airport Area Access Study are to ensure that:

- both regional and local citizens have the opportunity to participate in the planning process;
- citizens clearly understand the planning process, the evaluation methods and who is making decisions; and
- public input is ongoing as the technical process moves forward.

Public Involvement Challenge

The greatest public involvement challenge for the project was to involve regional audiences in the discussions. The resource limitations contributed to the challenge. The lack of any specific proposal at the beginning of the study created the additional challenge of drawing distracted or disinterested citizens throughout the local and regional areas.

Communicating with regional audiences presents an ancillary challenge to attract the news media to a subject that can seem uninteresting and provide few visuals. This proves particularly challenging in the initial phases of an MIS, because this type of study is a conceptual, long-range investigation which provides directions for future planning efforts.

Public input in the initial phases of an MIS should help define the uses of roadways in a corridor, the concerns users have about transportation and the ideas users have about solutions to congestion and circulation. This provides the engineering team with information about problem areas and an idea about what solutions the public may find acceptable.

Public Involvement Solution

The client and consultant team for the I-96/Airport Area Access Study met the public involvement challenges by "bringing the project to citizens" rather than relying on citizens to come forward with their comments. The concept was based on the principle that by attracting the news media and through the use of advertising, information about the study would be disseminated over a large distance and to the users of the current airport access routes.

Internal Elements

Before going "public" with information about the study, internal mechanisms were established to receive public input. These include a telephone hot line, a U.S. mail address and a website address. The phone number and addresses appear on all project-related materials. A log form was created to record contacts with the public through each of the mechanisms.

In addition, a database was created to include the names of all public and elected officials, media entities, major employers, business associations and neighborhood organizations in the local and regional areas.

External Elements

The primary focus of external activities for the project was to attract and maintain the interest of the news media in the study. The secondary focus of external activities was specialized communications to target local users and residents.

News Media

Attracting the news media to any activity has the ability to inform a wide audience about the activity, particularly television. News coverage reaches thousands of people in their homes and cars and can effectively communicate with a widely dispersed audience. However, to attract the news media, a way must be found to "hook" their attention.

The I-96/Airport Area Access Study utilized an innovative approach to gathering initial input by using a technique for communicating with roadway users, which in turn, attracted the news media. The goal was to widely disseminate information about the study and to encourage citizens to participate from their homes, their cars and their places of employment. An extensive media campaign was developed that utilized various mass-audience advertising mediums.

Specifically, the project employed the use of billboards that encouraged citizens to get involved with the project and radio spots during morning traffic reports. The billboards and radio ads displayed and broadcast the telephone hot line number. The billboard provided attractive visuals for the television media, and the use of an innovative approach to gathering public input drew all area reporters to a news conference held to kick-off the public involvement campaign.

Specialized Communications with Local Users and Public Officials

The billboards themselves helped to communicate the project and the hot line to users of the roadways central to the study area. Billboards were placed at the single exit from I-96 to the airport and along the roadway leading to the airport.

Letters of correspondence and newsletters were sent to local public and elected officials, major employers and community organizations. These materials helped communicate details about the study process, the technical elements of the study and the people involved in the decisions. Additional specialized communications with public officials proactively kept these individuals informed about the project.

Two community-based committees were formed early-on in the public involvement program to make sure local officials, business owners and residents were included in the discussions. A Steering Team, comprised of representatives of federal, state and local governments, the airport and other jurisdictional authorities was formed. A Community Resource Council, comprised of representatives of local businesses, homeowner associations and neighborhood groups, also was created.

Other Communication Tools

There are many other communication tools that can be applied when conducting a public involvement program. The I-96/Airport Area Access Study also utilized fact sheets and newsletters to provide information to people contacting the study team. Posters were sent to major employers in the area for display on employee bulletin boards.

Media Campaign Results

The ability to attract area media and the response from citizens throughout the metropolitan area exceeded expectations. The media conference was attended by two of the three local television news stations, and several print and radio news reporters. Stories about the project and the telephone hot line appeared on television and in three local newspapers. Several radio stations carried news coverage of the project. In addition, users of local roadways who saw the billboards responded, some from their car phones.

This resulted in a large number of telephone calls to the hot line over the course of the three days subsequent to the media conference. A total of 191 calls was received in the first 72 hours of hot line operation.

Anyone making contact with the project team and providing their name and address were added to the project mailing list. Fact sheets about the project were sent to all people who requested information. This included both regional and local citizens.

People responding to the media campaign provided useful information to the study team regarding their thoughts on specific solutions to traffic congestion in and around the airport. The following table provides a breakdown of public comments received relative to their potential transportation solution.

Continued Involvement

As the study has progressed, citizens and the local media continue to be informed about the study through newsletters, media releases and other communication tools. Media follow-up has caused television, radio and print reporters to broadcast and publish additional stories about the project, including the announcement of public meetings.

Resources

Comparatively speaking, the costs for conducting a media campaign can be similar to the costs incurred to hold a public meeting. The costs for the external elements of the I-96/Airport Area Access Study are listed in the following table.

However, considering the level of participation that typically is experienced with an initial public meeting, the media campaign clearly draws more attention and involvement. That involvement also includes citizens who normally would not attend a public meeting. Overall, there can be more return on the investment of resources through the use of a media campaign.

A Note of Caution about the Media

Although the news media is a tremendous vehicle for getting your message out, there are some negatives to consider when working with the media. There is no guarantee that the media will find your story interesting or newsworthy, thereby eliminating their desire to cover the issue. Another significant event in the community could eclipse your success at attracting the media. The media, if not accurately informed, can distort the message you are trying to send, thereby reducing the effectiveness of using the media. And, it can be difficult to sustain the interest of the media.

Conclusions

The I-96/Airport Area Access Study has been effective in involving both regional and local publics in the planning process. The use of an innovative media campaign, which “hooked” the news media, directly contributed to the success of that involvement. Public interest continues to have a major role in the project, in part because of the news media attention given to the issue.

The comments and ideas received from the public have assisted the study team and study sponsors in formulating transportation alternatives. The Kent County Road Commission and its partners have information from regional audiences that can be used as a balance is pursued between user needs, local interests and engineering principles.

Table 1. Summary of Public Comments

Public Comments	No. of Comments
No Build	16
Travel Demand Management (TDM)	0
Non-Motorized	1
Transit	7
Transportation Systems Management (TSM)	26
Build	141
Supportive Comments	29
Comments of Opposition	12
Miscellaneous	3

Table 2. External Media Costs

Item	Costs
Media Kits	$100
Newspaper Ads	$1,000
Radio Ads	$4,500
Billboard	$4,500
Posters	$2,000
TOTAL	$12,100

The Massachusetts Statewide Bicycle Transportation Plan

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Abstract

The Executive Office of Transportation and Construction (EOTC) and the Massachusetts Highway Department (MassHighway), with the support of Governor Paul Cellucci and under the direction of Secretary of Transportation Patrick J. Moynihan, launched the comprehensive *Statewide Bicycle Transportation Plan* in 1996 to develop policies and practices to improve conditions for bicycling in the Commonwealth. Secretary Moynihan released the plan at the April 1998 Metro Boston Trail Conference, where it received public and agency approval and media recognition. The success of the Massachusetts *Statewide Bicycle Transportation Plan* can be largely attributed to its extensive and innovative public involvement process.

As this is the first such Massachusetts statewide bicycle plan, EOTC and MassHighway invited a number of state agencies, bicycle community representatives, and the public to help identify bicycle transportation opportunities and needs in several broad areas, including highway planning, design, construction and maintenance practices, and transit connections. Particularly instrumental to the public involvement process was the formation of a User/Focus Group representing bicycle advocacy groups, business representatives, state legislators, and others familiar with bicycling issues and initiatives. The User/Focus Group provided valuable perspective throughout the entire planning process. After the 30-day public review period of the Final Draft Plan, the User/Focus Group also met with Highway Commissioner Kevin J. Sullivan to discuss the plan's outcome and implementation. Citizens were also extensively involved through two series of seven public information meetings held throughout the state, and review and comment on draft plan sections. For the first time, EOTC and MassHighway made project materials, including draft recommendations, available on the Internet and received public comments electronically (E-mail).

The *Executive Summary and Action Plan* are the nucleus of the larger plan; that portion reviews the public involvement process, the policy framework, and jurisdictional roles and responsibilities. The *Action Plan* is being carried out, in large part because of the strong support generated through the plan's public involvement process. Significant advances include:

- establishing the Bicycle Program Office under the direction of EOTC
- issuing MassHighway's *Engineering Directive E-98-003* addressing bicycle accommodation
- establishing a task force to revise MassHighway's 1994 publication, *Building Better Bicycling*, develop a more comprehensive bicycle manual, and present workshops on bicycle facility design
- hiring a Bicycle-Pedestrian Accommodation Engineer

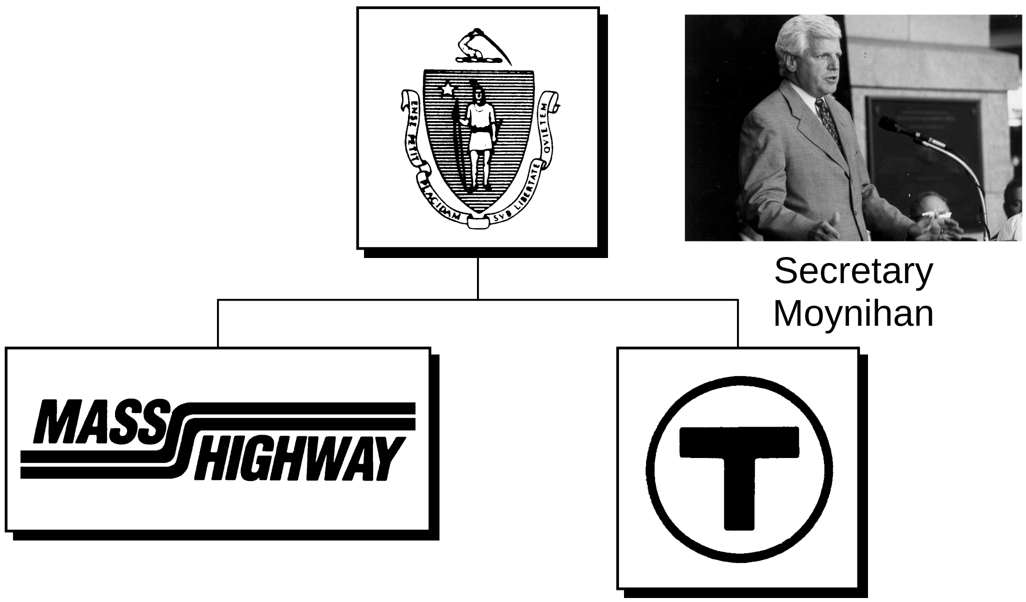
Introduction

Massachusetts Secretary of Transportation Patrick J. Moynihan introduced the Massachusetts Statewide Bicycle Transportation Plan at the Metro Boston Trails Conference in April 1998. In attendance at the conference were diverse interests: members of bicycling, walking, trail, greenway and environmental organizations; representatives of federal, regional, state and local agencies; legislators; and citizens from communities throughout the state. The Plan received positive feedback from the public and the press alike. The Plan was supported by a broad cross-section of stakeholders and interested parties, illustrating the central role of public involvement in the statewide planning process.

This paper will examine the public involvement and planning strategies that added value to the Massachusetts Statewide Bicycle Transportation Plan. It will also take a look at what the Plan has set in motion - policies and practices to improve conditions for bicycling in the Commonwealth.

The Planning Process - The Four Es

The Executive Office of Transportation and Construction (EOTC) and the Massachusetts Highway Department (MassHighway), under the leadership of Governor Paul Cellucci and the direction of then-Secretary Moynihan, launched the comprehensive Statewide Bicycle Transportation Plan. The planning process recognized the multi-dimensional quality of bicycle transportation, often characterized by "the 4Es": engineering, education, enforcement and encouragement. Though MassHighway's primary mission is commonly characterized by the first "E," engineering, the Plan was designed to be comprehensive in scope and to encompass all four elements. By enlarging the Plan's scope to incorporate enforcement, education and encouragement, its public involvement perspective and process were also broadened.



The planning process was further broadened by the EOTC's unique agency arrangement. Both MassHighway and the Massachusetts Bay Transportation Authority (MBTA) are under the EOTC's organizational umbrella, with the Secretary of EOTC also serving as Chairman of the MBTA Board. By providing a close working relationship with transit interests, this structure fostered a broader consideration of bicycling in relation to transit, including access to, parking at, and conveyance aboard transit. MassHighway recognized from the outset that the bicycle-riding public is, to some degree, a transit-riding public, and that bicycling would be best considered in a multimodal context.

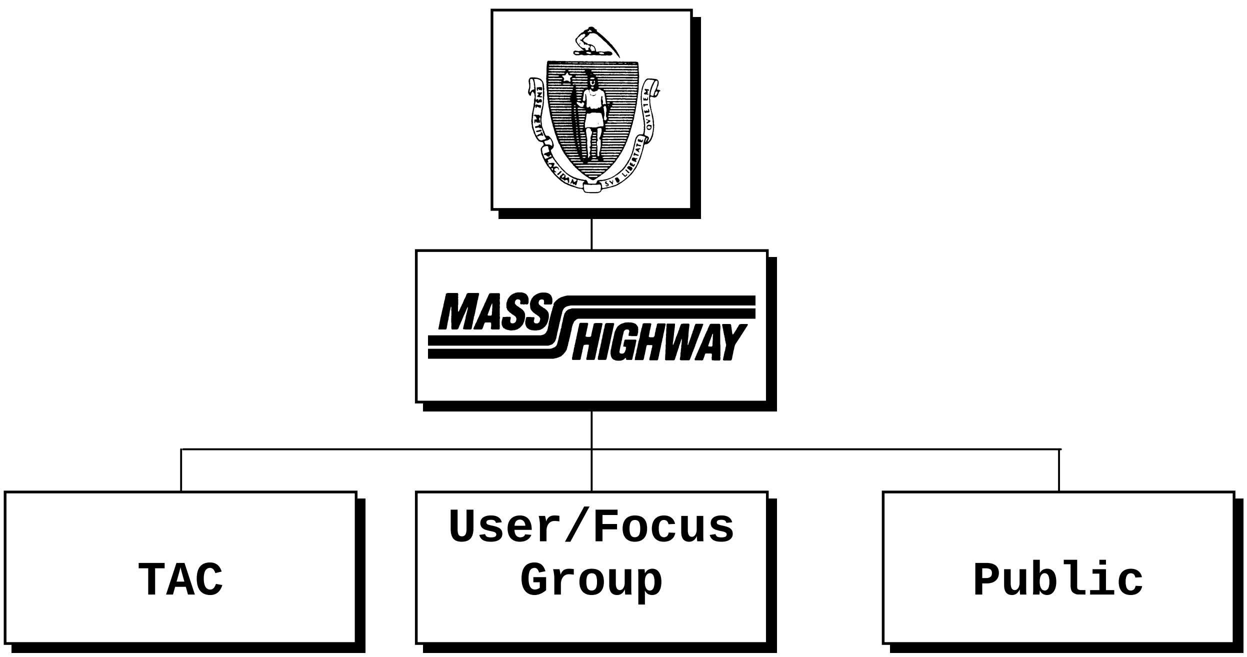
Consultant Selection and Team Members

Public involvement began early in the planning process. MassHighway wanted to ensure that the process would resonate well throughout the bicycling community and the broader public. In order to gather the input of bicycling interests and the agencies representing the state's thirteen planning regions, MassHighway sought representatives of the bicycling community and the Massachusetts Association of Regional Planning Agencies (MARPA) for the consultant selection committee. The legislative chair of the Charles River Wheelman, then the largest cycling club in the Commonwealth, provided a bicycling organizational perspective. In addition, the Senior

Planner with the Nantucket Planning & Economic Development Commission (NP&EDC), an agency with extensive bicycle planning experience, was chosen by MARPA to represent its interests on the consultant selection committee.

The selected consultant team demonstrated strong public involvement expertise and multidisciplinary skills. The lead consultant had extensive experience with bicycle facility planning and design and was well versed in building community support for projects as they moved to construction. One of the subconsultants was a large national organization with great depth in developing public support for the successful conversion of railroad rights-of-way to rail-trails. Another subconsultant was a small local firm whose principal enjoyed a high profile in the bicycling community. These attributes further served the objective of building a broad base of support for both the planning process and the Plan itself.

The inclusion of a leading highway traffic research center at a major university bolstered the Plan's enforcement and education perspectives. Having the center's staff on the consultant team ensured outreach to a broader agency base and bicycling constituency. For example, the Massachusetts Bicycle Safety Alliance, which represents an array of agencies, non-profit organizations and bicycling interests, became actively involved because of the Plan's mandate to include safety education and enforcement initiatives.



Technical Advisory Committee

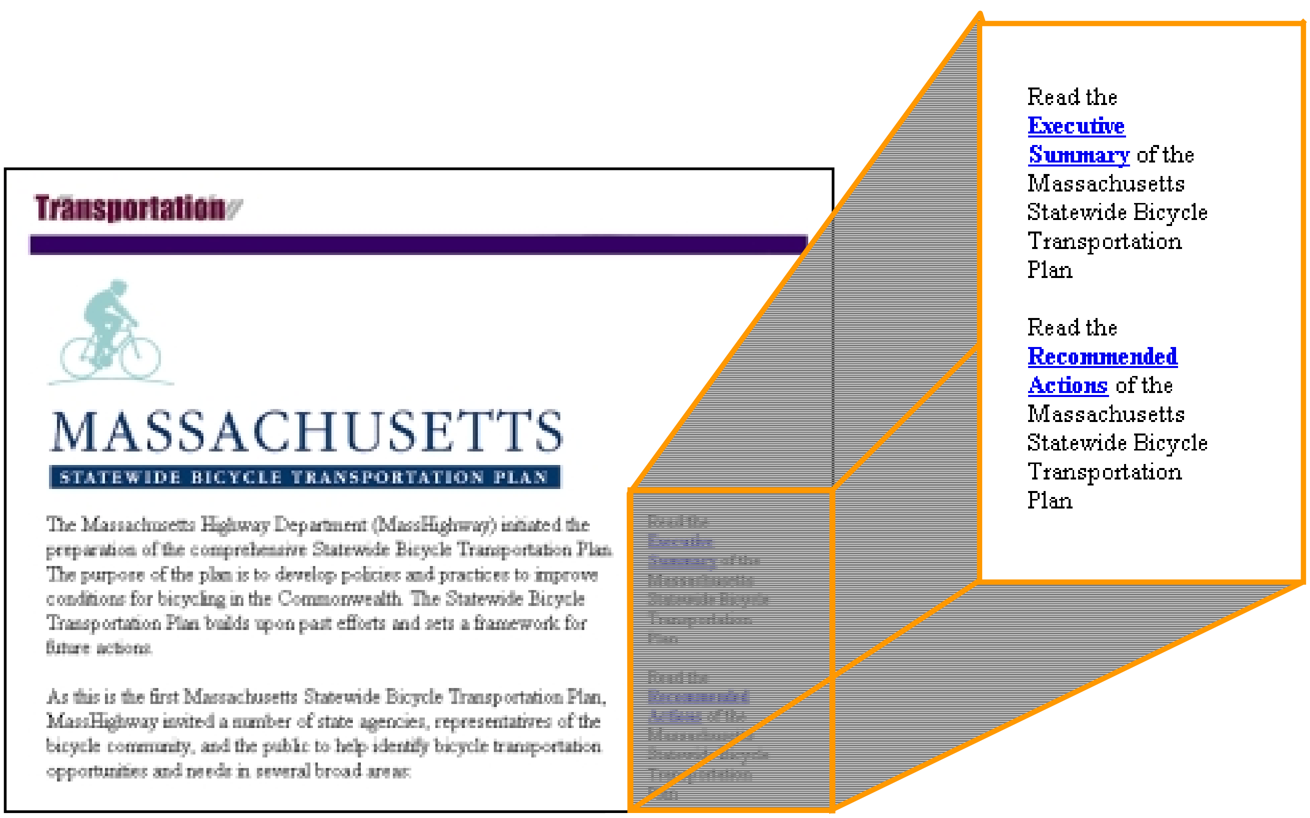
In addition to the consultant team, a Technical Advisory Committee (TAC) was created to provide broad-based agency guidance. The TAC represented EOTC's Office of Environmental Policy and MassHighway's Commissioner, Chief Engineer and Planning Director. Other state agencies included the MBTA, the Executive Office of Environmental Affairs and its Department of Environmental Management, the Governor's Highway Safety Bureau, the Office of Travel and Tourism, and the Department of Public Health. The Massachusetts Bicycle Advisory Board, composed of both agency personnel and cycling citizens, was represented. In addition, regional interests were represented by the same MARPA designee who had participated on the consultant selection committee, thus adding valuable continuity to the process. Further, municipal interests were represented by the coordinator of the City of Cambridge's bicycle and pedestrian program.

The User/Focus Group

A second advisory group was formed to represent the views of bicyclists, the bicycle industry, local interests, the Legislature, and others involved in bicycle transportation. This ten-member User/Focus Group included two representatives from bicycling organizations: the statewide Bicycle Coalition of Massachusetts (MassBike) and Mad About Cycling, a Cape Cod advocacy group. Two additional bicyclists were selected from attendees of statewide public meetings that were held at the beginning of the project.

The Massachusetts bicycle industry was represented by the owners of two prominent Boston-area bike shops and a major bicycle security equipment corporation. Local agency representatives on the User/Focus Group included a community bicycle police officer, a city planner, and a Transportation Management Association director. A Massachusetts State Representative also served on this second advisory board.

The User/Focus group met four times in 1996 and contributed to the major steps of the planning process: problem definition, analysis of alternatives, and development of recommendations. Members offered specific recommendations on design, maintenance, safety, transit, and other topics that were directly incorporated in the Plan. The group was insistent that all recommendations be assigned to a lead agency and that specific deadlines be given.



The final Action Plan in the Massachusetts Statewide Bicycle Transportation Plan responds to these requirements because of the efforts of the User/Focus Group and the leadership of then-MassHighway Commissioner Kevin J. Sullivan, who embraced the Plan. After the 30-day review period for the final Draft Plan, the User/Focus Group met with Commissioner Sullivan to discuss the Plan's outcome and implementation.

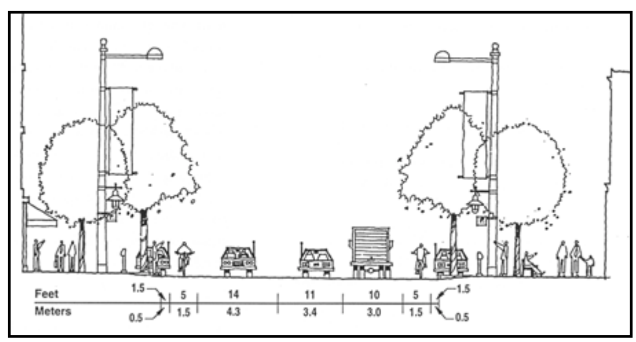
Public Meetings and Input

Commonwealth citizens were extensively involved in the planning process through two series of public information meetings that were held throughout the state. The first series of meetings was held in June 1996, at seven locations ranging from western Massachusetts to Cape Cod. Meetings were also held in Boston and in several suburbs. Special flyers, which included postage-paid comment cards, were distributed at the initial public meetings. Moreover, MassHighway used electronic mail and the Internet for the first time to inform the public and to receive comments and suggestions on the Plan.

The bicycle community was vocal at these meetings, advocating that MassHighway and EOTC use this opportunity to implement policy in support of the state bicycle and pedestrian legislation that had been signed into law in May 1996. That law directed that the MassHighway Commissioner make all reasonable provisions for the accommodation of bicycle and pedestrian traffic in the planning, design, and construction, reconstruction or maintenance of any project undertaken by the agency. MassHighway responded by developing several new engineering directives on bicycle and pedestrian accommodation during the course of the Plan's preparation.

In the fall of 1996, prior to the second round of public meetings, draft recommendations were posted on the Internet. MassHighway received extensive comments on the draft recommendations, most via e-mail. Some were lengthy, with specific edits and additions to the draft materials. MassBike incorporated various draft materials and notices on its website and also used its electronic mailing list to circulate ideas on potential comments and positions.

Existing Roadway



Proposed Bicycle Lanes
Massachusetts Avenue, Cambridge

The public was very receptive to the Plan's approach during the second series of public information meetings, which were held in November 1996. Many were enthused by the success of local bicycle group efforts, some of which had been supported by MassHighway and highlighted in the Plan. Others, however, expressed skepticism that the Plan's many positive recommendations would be implemented.

Action Plan and Implementation

The Executive Summary and Action Plan formed the nucleus of the Massachusetts Statewide Bicycle Transportation Plan. This section reviewed the public involvement process and the policy framework, as well as jurisdictional roles and responsibilities. Significant actions have been carried out since the release of the Plan, in large part because of the strong support generated through the Plan's public involvement process, the strong interest of Governor Cellucci, and the leadership of Secretary Moynihan and Commissioner Sullivan. These actions include:

- Establishing the Bicycle Program Office under the direction of EOTC, which has centralized agency action on bicycling issues and provided a means to bring key EOTC, MassHighway and MBTA staff together on a regular basis;
- Issuing MassHighway's Engineering Directive E-98-003 to address bicycle accommodation and to update two prior directives issued in response to the earlier legislative mandate;
- A Bicycle-Pedestrian Accommodation Engineer at MassHighway; and
- Establishing a task force to revise MassHighway's 1994 publication, Building Better
- Bicycling, developing a more comprehensive bicycle manual, and presenting workshops on bicycle facility design.

Each of these actions is critical to improving bicycling conditions in the Commonwealth, now and in the future. The update of MassHighway's Building Better Bicycling is just one example of the Plan's success.

A Work in Progress

In 1994, MassHighway published Building Better Bicycling, a manual for improving community bicycling conditions. There was an expectation that the manual would be updated as the state of the practice evolved. The Action Plan specified this update, and the progress to date demonstrates the influence of the public involvement process. The Bicycle Program Office has brought various elements of EOTC and MassHighway together on a regular basis to plan the second-generation manual.

A planning task force meets regularly to lay out the manual's format and content and to plan public workshops revolving around the manual. As with the Plan's TAC, the task force benefited from the involvement of many MassHighway participants: the Office of Commissioner Sullivan, the Chief Engineer's Office, the Design and Location Engineer, and Planning. Transportation Secretary Moynihan's strong stamp of approval of the Plan also bolstered the task force.

The public workshops crossed the Commonwealth from Cape Cod to the Connecticut River Valley and covered a variety of subjects: the engineering concerns of planning, design, construction, and maintenance, as well as enforcement, education and encouragement. MassHighway was able to introduce not only its latest policies and procedures, but also its current personnel, so that practitioners in the field could better identify who was responsible for what back in Boston.

The workshops, held in four locations in October and November 1998, were enormously successful. Attendance was far more than originally expected. Each session drew the anticipated 50 attendees, and then some. The concluding Worcester workshop attracted more than 70 people. The workshops drew staff from other state agencies, the regions and localities. The cycling community was well represented by members of local, regional and statewide organizations. Consultants rounded out the audience.

These workshops were designed as half-day sessions with lunch. The sit-down meal delivered a personal touch with professional yield, allowing headquarters staff to be seated among a wide array of interests. The manual should better serve its intended audience, local and regional practitioners, as a result of a continued and active public involvement process.

Conclusion

The Massachusetts Statewide Bicycle Transportation Plan represents a significant contribution to improving cycling conditions in the Commonwealth. The Plan's success demonstrates how public involvement can strengthen the statewide planning process.

The Plan benefited from EOTC's multimodal perspective and comprehensive "4E" approach. Constituent and community interests were built into the process from the outset, through both traditional and innovative means. From the consultant selection process and the creation of the TAC and User/Focus Groups to the use of the Internet as a vehicle for education and participation, the Massachusetts Statewide Bicycle Transportation Plan truly maximized the benefits of public involvement. As reported in The Boston Globe, "The detailed, 80-page plan does not instantly create more bike paths and lanes, but it commits the state to an aggressive set of pro-cyclist policies."

Census Transportation Planning Package (CTPP) 2000

Elaine Murakami, *Federal Highway Administration*

Abstract

We are only one year away from Census 2000, the census for the new millenium. Despite the battles over sampling for non-response, we are confident that there will be a census long form, and that it will include journey-to-work questions. FHWA, FTA, BTS, and AASHTO have been working with the Census Bureau to assure that we get a CTPP for 2000 that is usable, accurate, and delivered in a timely manner. By the time of the conference (March, 1999), MPOs will be developing new TAZs for submission to the Census Bureau Geography Division in a GIS format, and by summer of 1999, will be assisting with geocoding of known employers in their region. In the same time period, the CTPP table definition process will be in progress, with near final design by late fall 1999.

This session will be a status report of the various CTPP tasks that are in the field, or will soon be in the field. Because the MPOs and State DOTs play a critical role in the CTPP development and delivery, and we hope, will have an expanded role in workplace geocoding, this session is an important component of customer feedback for CTPP.

1. Introduction--Wende O'Neill, *Bureau of Transportation Statistics*

Decennial census data provide a baseline for metropolitan and state transportation planners' population and travel demand forecasts, as well as providing descriptive demographic information about neighborhoods. The large sample size allows for reporting at small geographic units with good accuracy.

Our goal for the Census Transportation Planning Package for 2000 is to provide the highest quality data in a timely manner. We are trying to be responsive to customer inputs from the 1990 experience. Topics will include: review the overall goals of the CTPP, review the schedule of events for decennial census and CTPP, and discuss the CTPP data in context with other local and national data collection efforts, including the American Community Survey.

2. TAZ Update--Jerry Everett, *Federal Highway Administration*, and Bob LaMacchia, *Census Bureau*

We are in the middle of the TAZ submission process. Because it is quicker and less prone to error than using paper maps, we have developed a GIS-based approach for MPOs to submit TAZ boundaries for CTPP. Submission of TAZs in calendar 1999, will allow TAZs to be added to the Census Bureau TIGER/Line prior to the 2000 Census, and will be added to the individual records from the decennial census. We believe that this will improve the timing of delivery of CTPP files to the data users. Review the TAZ submission process and the software.

3. Workplace Coding--Phil Salopek, *Census Bureau*

One of the criticisms of past CTPPs has been the lack of local involvement in workplace coding. That is, respondents have completed the census questionnaires and the Census Bureau has geocoded the responses, but there has been little, if any, opportunity to use local knowledge to improve the accuracy of the data. Because the employer reference files have been incomplete, and because respondents often do not provide clear address information for workplace location, many responses are not coded and are left to be geographically allocated based on the coded records. The Census Bureau is developing a process for local involvement in developing better employer reference files, and for local assistance in coding responses in post-processing. The more workplace addresses that are coded, the fewer that need to be allocated, the better the quality of data. Review the plan for local involvement and discuss the software design.

4. CTPP Table definition--Ed Christopher, *CATS*

The TRB Urban and Statewide Data committees, the TRB Census Data subcommittee, and the DOT/Census Bureau working group are developing specifications for the tables to be included in the CTPP. In talking with data users, we have found that Parts 1, 2, and 3 of the Urban Package, and Parts A, B, and C of the Statewide package were fairly widely used, while the other parts (large geographic units and 3- and 4-way cross-tabulations) were not. Changes in some of the questionnaire wording on the decennial census form, (e.g. hours worked, and potential changes in Census confidentiality review processes (aka “disclosure review”) will also impact the design of the tabulations. The need for other demographic characteristics to be tabulated as part of CTPP will be discussed, as will the need for “custom” 3- and 4-way tabulations.

5. Question and Answer Period

Experience in Estimating Joint Mode and Destination Choice in Portland (No Attraction Model)

Keith Lawton and Kyung-Hwa Kim, *Portland METRO*; and
Mark Bradley, *Bradley Research and Consulting*

Abstract

Most texts talk glibly about using the accessibility, or log sum values from the mode choice level as impedance for the destination choice. Tackling this in a naive way leads to unrealistic trip length distributions in practice. This would make model calibration impossible.

Described here is a practical approach combining estimation and calibration iteratively to yield a credible model of joint mode and primary destination choice. The process includes converting the impedance into a pseudo-time value, and method(s) to transform this time into a time function that will give a reasonable trip length distribution when estimated as a logit destination choice.

It should be noted that this process uses readily available "size" variables (employment by SIC for example, or households by income) at the destination zone, and as an allocation model does not require a trip generation attraction model. An attraction model could, in fact, be derived from the size variable relationships and an assumed scale variable to yield overall attractions to match productions, or any other source of aggregately estimated attraction model.

Presentation Outline

- Destination Choice as Distinct from Prod–Attr. & Gravity
- Logit Formulation
  - Structure
  - Impedance Variables
  - Size Variables
- Pseudo Attraction Eqns.
  - Relative weights
  - Scaling/Sharing
- Trip-Based Destination Choice Portland
  - With and Without Mode Choice Log Sum Variable
- Trip-Based Destination Choice in Salem
- Tour-Based Mode and Destination Choice Portland
  - Primary Destination & Mode – Work Tour
  - Use of Value of Time from Stated Preference
  - Simultaneous MNL (no nesting)
  - Rich Variable Set with Micro-Simulation/Sample Enumeration
    - Ref: A System of Activity-Based Models for Portland, Oregon (FHWA – CSI, Bradley & Metro)

Destination Choice

Distinct from Prod –Attr. & Gravity

Logit Formulation:

$$P(d,m) = \quad e^{U(d,m)} / SUM_{(d,m)}\, e^{U(d,m)}$$

$$U_{dm} = V_d + V_m + V_{dm}$$

V_d = Comp of util. For dest. (fn of size variables such as employment by type)

V_m = Comp of Util. For mode (fn of mode spec. dummy variable)

V_{dm} = Comp. Of Util. Specific to combination of d and m (such as in vehicle time by mode/destination combination)

Much Simpler if Destination Choice uses one mode (e.g. highway travel times/costs). Then only impedance, size variables and trip interchange constants are needed.

Examples of Simple Destination Choice

Portland & Salem, OR

Portland: (Alogit Output)
(Income > $35,000)

Converged	Yes
Observations	5647
Final log(L)	-11867.9
D.O.F.	10
$Rho^2(0)$	0.382
$Rho^2(c)$	0.382

TTime	-0.1999	(-16.7)
$TTime^2$	0.004275	(7.8)
$TTime^3$	-4.543e-5	(-6.4)
Wash > OR	-0.9737	(-14.3)
Or > Wash	-1.429	(-10.7)
Willamette W-E	-0.2918	(-4.4)
Willamette E-W	0.1782	(3.5)
SIZE VARIABLES*		
Retail Emp	1.000	(*)
Other Emp	0.3508	(3.6)
Service Emp	0.3534	(3.3)
Government Emp	0.2925	(2.6)

Size Variables

These replace “Attraction” and are estimated directly.

The discussion that follows is ALOGIT – specific

Multiple Size Variable ability is relatively new and needs careful interpretation:

1. The size variable is always taken as a log (because of the logit exp. Form)
2. There is always a “base” or reference size variable whose coefft is 1.
3. The Utility function has the (the U or V in e^U) form

U= a.(var1) + b.(var2) + .. +*ln(1.S1+exp(f.S2)+e(g.S3)+….)*

Where S1 is the reference size variable and S2, S3 etc. are the other size variables.

Thus the relative “attraction” of each size variable is computed for application.

Example From Portland Est.

Portland: (Alogit Output)
(Income > $35,000)

Converged		Yes
Observations		5647
Final log(L)		-11867.9
D.O.F.		10
$Rho^2(0)$		0.382
$Rho^2(c)$		0.382
TTime	-0.1999	(-16.7)
$TTime^2$	0.004275	(7.8)
$TTime^3$	-4.543e-5	(-6.4)
Wash > OR	-0.9737	(-14.3)
Or > Wash	-1.429	(-10.7)
Willamette W-E	-0.2918	(-4.4)
Willamette E-W	0.1782	(3.5)
SIZE VARIABLES*		
Retail Emp	1.000	1.0000
Other Emp	~~0.3508~~ >	1.4202
Service Emp	~~0.3534~~ >	1.4239
Government Emp	~~0.2925~~ >	1.3397

Expressed as an Attraction Equation

Relative Attractions = Retemp*.193 + OthEmp*.274 + ServEmp*.275 + GovEmp*.258

PORTLAND: TRIP BASED MODEL ESTIMATION

Trip Based Destination Choice - With and Without Mode Choice Logsum

	HBW Low Inc/util		HBW Low Inc/No Util		HBW Hi Inc/Util		HBW Hi Inc/No Util	
Converged	Yes		Yes		Yes		Yes	
Observations	2644		2644		5647		5647	
Final log(L)	-5426.6		-5432.6		-11864.0		-11867.9	
D.O.F.	7		6		11		10	
$Rho^2(0)$	0.397		0.396		0.382		0.382	
$Rho^2(c)$	0.395		0.394		0.382		0.382	
avgtt	-0.3216	(-15.5)	-0.3466	(-17.9)	-0.2130	(-16.2)	-0.1999	(-16.7)
avgttsq	0.01112	(10.9)	0.01105	(10.8)	0.004312	(7.9)	0.004275	(7.8)
avgttcb	-1.396e-4	(-9.0)	-1.376e-4	(-8.9)	-4.524e-5	(-6.3)	-4.543e-5	(-6.4)
washor	-1.214	(-10.9)	-1.261	(-11.4)	-0.9991	(-14.5)	-0.9737	(-14.3)
orwash	-1.571	(-7.6)	-1.663	(-8.1)	-1.477	(-10.9)	-1.429	(-10.7)
willameWE	-0.3876	(-3.5)	-0.3081	(-2.8)	-0.2828	(-4.2)	-0.2918	(-4.4)
willameEW					0.1488	(2.9)	0.1782	(3.5)
Mode Logsum	0.1595	(3.3)			-0.07650	(-2.5)		
Base Empl.	1.000	(*)	1.000	(*)	1.000	(*)	1.000	(*)
oth empl					0.3498	(3.6)	0.3508	(3.6)
serv empl					0.3264	(3.0)	0.3534	(3.3)
governm empl					0.2545	(2.3)	0.2925	(2.6)

Notes: Base Empl = Total Employment for cols. 1 & 2; Retail Employment for cols. 3 & 4

Oth = Other employment (Total – named size variables)

SALEM-KEIZER

Size variable coefficients as estimated

	HBW Low Income		HBW High Income	
	Coeff.	T-stat	Coeff.	T-stat
Time	-0.3427	-6.5	-0.1998	-44.6
Time Squared	0.0109	4.2	0.0038	3.7
Bridge				
SIZE VARIABLES (EMP)				
Retail	1.0000	0.0	1.0000	0.0
Other			0.4902	3.9
Service			0.2799	1.8
Government			0.2799	2.1
Total Employment	-0.5189	-2.5		

	HBO		HBRecreation		HBShop	
	Coeff.	T-stat	Coeff.	T-stat	Coeff.	T-stat
Time	-0.5500	-44.6	-0.5057	-32.1	-0.6073	-28.6
Time Squared	0.0150	23.4	0.0145	17.1	0.0175	14.3
Bridge	-0.4732	-8.2	-0.1480	-2.1	-0.8655	-9.1
SIZE VARIABLES (EMP)						
Retail	1.0000	0.0			1.0000	0.0
Other	-2.3991	-25.7			-5.1673	-12.6
Service	-3.0200	-17.2			-7.2644	-3.4
Government	-2.6521	-28.0			-4.1669	-20.2
NonRetail						
Total Employment			1.0000	0.0		
Households	-1.7193	-46.6	0.8593	15.4	-3.5234	-46.4
Park			4.5750	60.3		

	NonHBW		NonHNW	
	Coeff.	T-stat	Coeff.	T-stat
Time	-0.4807	-17.0	-0.4699	-27.8
Time Squared	0.0158	8.3	0.0146	13.1
Bridge	-0.2604	-1.8	-0.2022	-2.4
SIZE VARIABLES(EMP)				
Retail	1.0000	0.0	1.0000	0.0
Other	-1.3261	-9.7	-2.6423	-18.3
Service	-3.6945	-7.6	-2.5133	-16.7
Government	-1.9633	-11.1	-2.7303	-22.0
Households	-1.9519	-16.9	-1.7048	-33.6

NOTE: Size variables as reported by ALOGIT in the form: ln(1.Base+exp(c2)*var2+exp(c3).var3+….)
So that the relationship in application has the relative relationship as seen on the next page

SALEM-KEIZER

Size Variables for application SIZE variables represent exp(estimated value)

	HBW Low Income		HBW High Income	
	Coeff.	**T-stat**	**Coeff.**	**T-stat**
Time	-0.3427	-6.5	-0.1998	-44.6
Time Squared	0.0109	4.2	0.0038	3.7
Bridge				
SIZE VARIABLES (EMP)				
Retail	1.0000	0.0	1.0000	0.0
Other			1.6326	3.9
Service			1.3230	1.8
Government			1.3230	2.1
Total Employment	0.5952	-2.5		

	HBO		HBRecreation		HBShop	
	Coeff.	**T-stat**	**Coeff.**	**T-stat**	**Coeff.**	**T-stat**
Time	-0.5500	-44.6	-0.5057	-32.1	-0.6073	-28.6
Time Squared	0.0150	23.4	0.0145	17.1	0.01746	14.3
Bridge	-0.4732	-8.2	-0.148	-2.1	-0.8655	-9.1
SIZE VARIABLES (EMP)						
Retail	1.0000	0.0			1	0
Other	0.0908	-25.7			0.0057	-12.6
Service	0.0488	-17.2			0.0007	-3.4
Government	0.0705	-28.0			0.0155	-20.2
Total Employment			1	0		
Households	0.1792	-46.6	2.3615	15.4	0.0295	-46.4
Park			97.028	60.3		

	NonHBW		NonHNW	
	Coeff.	**T-stat**	**Coeff.**	**T-stat**
Time	-0.4807	-17	-0.4699	-27.8
Time Squared	0.0158	8.3	0.0146	13.1
Bridge	-0.2604	-1.8	-0.2022	-2.4
SIZE VARIABLES (EMP)				
Retail	1	0	1	0
Other	0.2655	-9.7	0.0712	-18.3
Service	0.02486	-7.6	0.081	-16.7
Government	0.1404	-11.1	0.0652	-22
Households	0.142	-16.9	0.1818	-33.6

Extracted From: A System of Activity-Based Models for Portland, Oregon (FHWA – CSI, Bradley & Metro)

1.3. Home-base tour mode/destination choice models

Again, there are three different models, corresponding to the work/school, maintenance and discretionary tour purposes. We distinguish 9 different modes:

(1)	DA	drive alone
(2)	DP	drive with passenger
(3)	PA	car passenger
(4)	MW	MAX/walk access
(5)	MP	MAX/park and ride
(6)	BW	bus/walk access
(7)	BP	bus/park and ride
(8)	BI	bicycle
(9)	WA	walk only

For application, 21 different destination zones are used, as described in an earlier memo:

(1)	the residence zone
(2-5)	4 zones sampled from a distance less than D1
(6-9)	4 zones sampled from a distance between D1 and D2 and employment < E
(10-13)	4 zones sampled from a distance between D1 and D2 and employment > E
(14-17)	4 zones sampled from a distance greater than D2 and employment < E
(18-21)	4 zones sampled from a distance greater than D2 and employment > E,

where D1 = the 20th percentile distance of all actual tour destinations for the purpose
D2 = the 60th percentile distance of all actual tour destinations for the purpose
E = the 50th percentile employment of all actual tour destinations for the purpose
(total empoyment used for work/school,
retail+service employment used for maintenance,
retail+service employment + households used for discretionary)

The maximum number of available alternatives is 21 destinations x 9 modes = 189. Alternatives are unavailable if the travel time in the data is greater than 240 minutes (only occurs for bike and walk over long distances) or less than 0 (only occurs for transit alternatives that aren't connected in the networks). The transit modes are made unavailable for intra-zonal alternatives, or if the network wait time is greater than 120 minutes. Only one of the two park and ride alternatives is available for any individual depending on what type of park and ride lot is in the zonal data file for that residence zone. Finally, the two car driver alternatives are unavailable for households that do not own any vehicles. (Data on driver's license was not used in the models because it is not available in the PUMS data being used to apply the models.)

The mode/destination models use household and person data as well as network distance, time and cost data. In the course of extensive testing, it was found that the RP data would not support estimation of reasonable coefficients for both the time and cost variables for any of the tour purposes. This is probably due to the fact that both parking costs and traffic congestion are fairly low (at least at the level of definition in the data), meaning that both car costs and car travel times are strong related to distance and thus highly correlated with each other. Another possible explanation is that there is very low transit usage in Portland, and those who do use transit may be basing their choice on factors other than travel time and cost.

For these reasons, a decision was made to constrain the values of travel time to be equal to those estimated from the concurrent Stated Preference survey. Another attractive feature of the SP data is that it looked directly at reactions to congestion pricing - an important policy measure to be analyzed with the model and which does not exist in Portland presently. The SP-based values of time were estimated separately for home-work trips and home-other trips, and were estimated for three different income classes. The results are shown in Table 4 below. The variation is greater between income classes than it is between purposes, particularly for the work trips.

Table 4: Values of Time Estimated from Stated Preference Data
(All values in cents per minute, except for Transit Boardings)

Purpose	Home to Work			Home to Other		
Income	Less than $30,000	$30-60,000	More than $60,000	Less than $30,000	$30-60,000	More than $60,000
Drive alone In-vehicle	8.9	12.3	17.7	12.2	12.2	23.7
Drive w/pass. In-vehicle	9.4	13.1	18.8	7.9	7.9	15.3
Transit In-vehicle	5.8	8.1	11.6	1.6	1.6	3.1
Transit Walk	21.5	29.7	42.8	29.4	29.4	56.9
Transit Headway	4.9	6.8	9.8	9.8	9.8	19.0
Transit Boardings	39.0	53.9	77.8	75.0	75.0	145.2

```
Coefficients as estimated from the SP survey:

                                       Work     Non-work
Travel cost ($)- everyone             -0.3274   -0.2641
Travel cost ($)- income under 30K     -0.1250   -0.0000
Travel cost ($)- income over 60K       0.1004   +0.1277
IVT (min)- drive alone                -0.04027  -0.03334
IVT (min)- drive with passenger       -0.04274  -0.02083
IVT (min)- transit                    -0.02636  -0.00421
Walk (min)- transit                   -0.09708  -0.07766
Wait (min)- transit                   -0.02221  -0.02596
Transfers- transit                    -0.1765   -0.1981

These are applied to the values in the LOS binary files as is, except
that total wait time is capped at 2 hours (round trip).
```

These values were used to calculate "generalized time" for the car and transit modes (the total time and cost utility divided by the car drive alone time coefficient), which was used as a variable in the mode/destination choice models shown below in Table 5. In each of the three models, a function was estimated that contained linear, quadratic and cubic terms for the generalized time. The results are highly significant, with the same general shape in all the models. The function is slightly S-shaped, with disutility rising sharply at first, then leveling off a bit, and then rising more sharply again at very high travel times. This function gives a reasonable match to the actual distribution of tour distances in the data for all modes.

The other mode-specific variables in the models are mostly related to age, gender and household type. The car availability variables are very strong, particularly for the car driver and transit alternatives.

Several of the destination-specific land use density variables are also very significant. This indicates that the size variables as defined do not fully account for the attractiveness of the zones.

Table 5: Home Based Tour Mode/Destination Choice Models

Tour type	**Work/School**		**Maintenance**		**Discretionary**	
Observations	7353		5852		3488	
Final log(L)	-23455.8		-20186		-13660.5	
Rho-squared (0)	0.335		0.284		0.188	
Alternative / variable	**Coefficient**	**T-st.**	**Coefficient**	**T-st.**	**Coefficient**	**T-st.**
Car and transit modes						
SP-based generalized time (min)	-0.06668	-23.2	-0.1763	-36.7	-0.1262	-21.2
SP-based generalized time squared	3.52E-04	8.3	0.001514	14.7	7.70E-04	6.9
SP-based generalized time cubed	-1.10E-06	-6.3	-5.59E-06	-9.3	-2.03E-06	-3.6
Drive alone						
Car competition in hhld*	-1.981	-19.5	-0.8392	-9.5	-1.163	-7.5
Age under 20	-1.292	-9.7	-0.4316	-2.1	-0.5352	-3.1
Age over 45	0.2951	3.9	0.2722	3.6		
Age over 65			-0.3434	-3.7		
Income over 45K			0.2389	3.8		
Children under age 5 in hhld	0.2937	2.7	-0.357	-3		
Female in 2+ adult HH, 1+ non-worker	-0.4483	-3.6				
2+ adults in household, all workers	0.1852	2.3			-0.2505	-2.6
No intermediate stops	-0.6925	-9.3	0.1852	2.3		
Secondary tour			0.3176	4	-0.3256	-3.1
Leave home before AM peak	-0.265	-2.1	1.115	3.5	0.8652	2.5
Leave home during AM peak	-0.1664	-1.9	0.5792	6.2	0.5061	3.8
Drive with passenger						
Constant	-3.334	-16.4	-1.593	-11.6	-1.512	-9.4
Log of distance (miles)	-0.4338	-10.6	-0.3063	-10.8	-0.4475	-12.1
Car competition in hhld*	-0.9051	-5.1	-0.5058	-5.1	-0.9564	-5.9
Age under 25	-0.3338	-1.8	-0.7288	-4	-1.204	-7.2
Male	0.651	4.6			0.4878	4
Children in household			0.406	4.3		
Female, children under 5 in hhld	1.317	6.1	1.388	10.2	1.391	8.5
Female, children 5 to 11 in hhld			0.6648	5.7	0.8226	5.3
Male in 2+ adult HH, 1+ non-worker	-1.026	-4.3	0.5894	6.6	0.3886	2.9
Single adult, no children in hhld	-1.814	-4.9	-1.596	-8.4	-1.591	-8.7
Intermediate stop on way from home	1.014	7.5	0.1306	1.5	0.3891	3.1
Intermediate stop on way back home	0.8121	5.6	0.2859	3.2	0.2749	2
Leave home in PM peak or later			0.6638	8.2	0.7675	7.6
Car passenger						
Constant	-2.671	-15.5	-2.41	-16.3	-2.017	-11.2
Car competition in hhld*					-0.5533	-3.4
Age under 25	0.6181	4.7	0.744	4.6		
Female	0.3747	3.5	0.7871	8.4	1.142	11.2
2+ adults, 1+ non-worker, no children			0.553	5.4	0.3525	3.2
Single adult	-0.9054	-4.9	-1.197	-7.5	-1.113	-7.3
Secondary tour			-0.5366	-4.9	-0.7501	-5.8
Leave home before AM peak	-0.558	-3	0.8411	2	1.201	2.8
Return home after PM peak	-0.6223	-3.4	0.6168	4.6	0.6849	4.5
Leave home in PM peak or later			0.6518	4.9	0.669	3.9

Table 5 Continued: Mode/Destination Choice Models

Tour type	Work/School		Maintenance		Discretionary	
Walk Access Transit						
Constant	-4.536	-7.3	-4.541	-3.8	-2.416	-1.7
MAX LRT constant	-0.319	-2.1	-1.712	-2.3	-0.5283	-1.2
No car in household	1.045	5.9	2.178	6.5	1.917	4.8
Car competition in hhld*			0.8529	2.3	0.8264	2.2
Secondary tour			-0.5801	-2	-1.611	-5.1
Hhld within 1/4 mi of transit, origin zone	1.73	6.4	4.561	3.8	0.5758	0.9
Empl. within 1/4 mi. of transit, dest.zone	1.875	3.2			1.62	1.2
Park and ride						
Constant	-4.553	-3.8	-1.169	-2.9	-1.418	-2.7
MAX LRT constant	-0.319	-2.1	-1.712	-2.3	-0.5283	-1.2
Car competition in hhld*	-0.8869	-3.5				
Secondary tour			-1.979	-1.8	-2.069	-3.4
Return home after PM peak	-2.353	-3.3				
Mixed use within half mile of dest.zone	3.14E-04	4.8			4.19E-04	1.9
Empl. within 1/4 mi. of transit, dest.zone	2.223	1.8				
Bicycle						
Constant	-3.24	-10.2	-3.772	-10	-3.184	-9.3
Travel time (min)	-0.09731	-6.2	-0.1107	-8	-0.0925	-7.6
Travel time squared	4.88E-04	2.2				
Travel time cubed	-9.95E-07	-1.3				
Female	-0.9397	-4	-0.5491	-1.7	-0.7731	-2.1
Mixed use within half mile of origin.zone			5.19E-04	3.4		
Mixed use within half mile of dest.zone	2.12E-04	2.7				
Walk only						
Constant	-1.496	-7	-2.828	-11.2	-1.94	-7
Travel time (min)	-0.0422	-19.9	-0.04804	-18.1	-0.03695	-18
Age under 20	0.7079	3.3				
Age under 35	0.4211	2.8				
Female, children under 5 in hhld			1.224	5.5	0.614	2.3
Female, children 5 to 11 in hhld			1.177	6.2		
No intermediate stops			1.502	8	1.239	5.5
Secondary tour			0.3535	2.2		
Mixed use within half mile of origin.zone			6.06E-04	8		
Mixed use within half mile of dest.zone	2.78E-04	5				
Origin zone dummy	0.4912	2.5	1.128	7.1	1.714	10
Destination land use						
Origin zone dummy	0.3622	3.4	0.2781	3.9	0.3104	3
Household within half-mile radius			3.34E-04	11.4	3.33E-04	8.5
Mixed use within half-mile radius			-0.00102	-14.1	-7.60E-04	-8.1
Employment within half-mile radius	3.55E-05	18			3.78E-05	9.2
Retail empl. within half-mile radius	-1.91E-04	-10	1.63E-04	8	-1.97E-04	-5.7
Fraction of land used for recreation	1.161	7.6			2.026	9.1
Log of relevant size variable**	1	constr	1	constr	1	constr

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Calibration Of Near Microsimulation Destination And Mode Choice Models

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Abstract

A regional model that simulates individuals' mode choice behavior was developed at the Chicago Area Transportation Study nearly twenty-five years ago. A new regional model currently being evaluated at CATS extends this approach to both destination and mode choice. Travel decisions of household members - workers, non-working adults and children - are reproduced by Monte Carlo simulation of individual behavior using destination and mode choice probabilities from logit choice models. Household characteristics of travelers are obtained by randomly sampling household type distributions within zone of residence. Trips are successively simulated from home, place of work and locations other than home or work.

The paper discusses the calibration and validation of the vehicle mode and destination choice models embedded in this simulation model. Destination and mode choices are not modeled in the typical sequence of travel demand models. The probability of selecting a destination zone when the mode of travel is known is first estimated as a function of destination attractions and the modal travel impedance between origin and destination. Mode choice probabilities are then calculated prior to selection of a destination and linked to destination choice through mode specific 'logsum" variables constructed from the denominators of the destination choice models. Other independent variables affecting mode choice are household characteristics and the prior mode used by the traveler when the trip is not home based. Monte Carlo methods are applied to select a vehicle mode for the trip based upon the mode choice probabilities, followed by a destination determined from the estimated destination choice probabilities for the selected mode.

Model calibration topics include development of the calibration data sets from household travel survey data and interpretation of the calibration results. The paper concludes with a few comments on the practicality and advantages of this modeling approach.

The Chicago Area Transportation Study's mode choice model developed in the 1970s is an early example of simulation ( ) in travel demand models. This model simulates the mode choices of travelers using Monte Carlo methods and choice probabilities from a logit mode choice model. This simulation approach is extended in a new regional travel model to both destination and mode choices. Travel decisions of individuals are simulated at a level of detail that approximates microsimulation, while maintaining compatibility with existing travel demand software, network coding and other forecasting procedures in the agency. Data for all model calibration were obtained from a conventional household travel survey conducted by CATS in 1990 ( ).

Geographic Levels in the Model

Two zone systems are resident within the model to deal with the different scales of non-motorized and vehicle travel. Regional zones comparable to those in conventional vehicle travel models are employed for the majority of the vehicle calculations. Network coding and skimming of networks to obtain zone-to-zone travel times and costs are carried out with the EMME/2 ( ) software, and time and cost matrices are stored in EMME/2 formatted databanks matching this set of zones.

Many of the calculations in the model require a second set of smaller sub-zones that can be summarized into the larger vehicle zones. These sub-zones figure most prominently in non-motorized sub-models and in the estimation of the walk and auto access distances to reach transit. The smaller sub-zones are utilized in these parts of the simulation to more accurately measure non-motorized travel distances and the destination attractions that can be reached by walking or cycling.

The two sets of zones are shown in Figure 1. There are 1778 vehicle zones covering the northeastern Illinois region and adjacent portions of Indiana and Wisconsin. Nearly all of the study area zones in Illinois follow a regular grid pattern based upon survey townships approximately six miles on a side and sections of townships that are generally one square mile in size. Although they can barely be discerned in the figure, there are 18,121 non-motorized sub-zones underneath the vehicle zones. In the portion of the region where zones follow a regular grid pattern, the non-motorized zones are quarter sections, one-half mile on a side.

Households and Trip Types Simulated

A mathematical process commonly used in trip generation models converts average household size and income by sub-zone into 224 household category probabilities. Each household category is defined by an income quartile and combination of adult workers, non-working adults and children aged twelve to fifteen in the household. Households in the sub-zone are synthesized using Monte Carlo methods and these household category probabilities. After establishing the basic characteristics of the household, a logit vehicle ownership model estimates the probabilities of different levels of vehicle availability for the household. Another Monte Carlo process then determines the number of vehicles in the household.

Trip productions and attractions define the trips to be simulated. Trips from or to home are always produced at home regardless of direction. Trips to or from work, excepting home to work or work to home trips, are produced at the workplace. The production end of all remaining trips without a home or work trip end is defined by the order they occur away from home or work. Table 1 shows the relationship between persons, trip productions and trip purposes.

Sequence of Trip Simulations

The order in which trips are simulated is shown in Figure 2. The model proceeds household by household. Worker home based trips are initially simulated, followed by home based trips for the household's non-working adults and children. The household level simulations are then repeated for all sub-zones. Temporary files containing home - work, home - shop and home - other trip destination and mode choices are written as the model simulates household travel.

After completing the household simulations, the home - work temporary file is read and tabulated by workplace sub-zone, household category, and home – work travel mode. The model then simulates worker travel by workplace sub-zone, repeating the workplace trip simulations for all sub-zones. Another temporary file is written to retain the destination choice, worker household characteristics and mode from work for work - shop and work - other trips.

The home - shop and home - other temporary files are next read along with the work - shop and work - other simulation results. Records in these files are summarized by worker and non-worker status, sub-zone of non-home/non-work attraction, household category, and previous travel mode. Mode and destination choices for all non-home/non-work trip productions (termed other - other trips in Figure 2) are then simulated in the same manner as home and work based trip productions. Temporary mode and destination choice files are again written during this simulation of other - other trips. These scratch files are read and a second round of other - other trips simulated for trips with new non-home/non-work productions. This model is not a true travel simulation since trip itineraries are not simulated. Instead, each household member has a fixed ordered pattern of daily trips. Figure 3 shows the simulated trip purposes and ordering of trip production locations for workers, non-workers and children. The trip production location for the first other - other trip (shown as a dashed line in the figure) is randomly assigned to a shop or other attraction location using the probabilities in Figure 3, which were obtained from the household travel survey.

As the simulation progresses, values corresponding to the production - attraction trips shown in Figure 3 are summarized into eighteen trip tables and written to an EMME/2 formatted output databank. The values written into a trip table cell are the product of:

1. An average daily trip generation rate for the trip purpose calculated from the household travel survey ( ). These rates are cross-classified by person type, household category and vehicle ownership.

2. A person weight, which is one, except for unusually large households.

3. A household weight, which is the inverse of the sample rate of households simulated.

4. A factor that is applied only to the other - other trips. It determines whether the trip is the first or second other - other trip to be simulated.

Destination and Mode Choice Models in the Simulation

Figure 4 shows the mode and destination choice models for home - work trips for workers in households with vehicles.

The home - work trip is first assigned to either non-motorized or vehicle modes. If the trip is non-motorized, a workplace sub-zone is selected. The non-motorized trip is multiplied by the appropriate weights and written into a walk/bike trip table in the output databank. These non-motorized models are described in a recent paper ( ), and will not be discussed further.

Six modes are considered in vehicle mode choice, and there are six modal destination choice models. Transit destination choice models are further complicated by the transit sub-mode and station choices nested in their destination choice models. Walk to transit contains two sub-modes depending on whether a transit path includes one or more commuter rail boardings. The drive alone to transit mode and the ride share to transit mode consider station choice within destination choice. Destination choice probabilities for trips via the four closest park and ride stations are calculated, including the three closest commuter rail park and ride stations and the nearest rail transit or express bus station.

Vehicle Destination Choice Models

The vehicle destination choice models have the same general logit formulation, regardless of the mode or trip purpose under consideration. From any production zone i, the probability of selecting a destination attraction zone j via a specific mode is as follows:

$$P_{ij} = \frac{W_j e^{I_{ij}}}{\sum_j W_j e^{I_{ij}}}.$$

In this equation, Iij is the travel impedance between zone i and zone j using one of the possible modes. This travel impedance is a linear combination of variables such as travel time or travel cost between zones. The quantity Wj measures the attractiveness of zone j for the trip purpose. These attractiveness measures are always some type of employment or a linear combination of employment and households. To calibrate the model, the ALOGIT software ( ) estimates the weights that should be attached to the independent variables in the impedance function using a maximum likelihood procedure. Relative weights for households and employment types are also estimated when the zone attractiveness measure includes two or more variables.

The original approach was to complete the ALOGIT model calibration, and then to code the destination choice coefficients into the regional simulation program. Evaluation of the destination choice calibration could not continue until mode choice calibration was completed, and the travel simulation run to produce a trip table that could be compared against the household travel survey. This proved to be time consuming, and the final comparison of simulated and survey trips offered little insight into how to best reformulate or adjust the impedance equations since the simulation results were the product of mode choice as well as destination choice models.

Fortunately, the ALOGIT software has an option that allows for some evaluation of the destination choice calibration without running the full simulation. Tables can be produced using the program's APPLY function to compare the trip length frequency of observed (household survey) trips against the trip length frequency predicted by the calibrated destination choice model. The modeled trips are based on calibrated impedance coefficients, and the trip and destination zone characteristics in the calibration data set.

The following example illustrates how the APPLY trip length tables were utilized in the calibration of the drive alone home - work trips for workers from households with at least one vehicle per worker. The original drive alone impedance function was the following equation:

$$I_{ij} = -0.0114 * ivt_{ij} + 0.197\mathrm{E}-05 * opp_{ij} - 2.358 * op\cos t_{ij} - 0.334 * pk\cos t_{j} - 0.367 * den_{j}.$$

This equation defines the drive alone impedance (Iij) between home zone i and workplace zone j in terms of five independent variables:

1. AM peak period in-vehicle time in minutes.

2. The number of employment opportunities between home and workplace matching the household income quartile (the employment closer to the home zone than the destination workplace zone).

3. The direct auto operating cost in dollars (fuel and other operating costs that vary with distance and travel speed).

4. The daily central area parking cost in dollars from a central area parking model ( ) when the workplace zone is in the central area. This parking cost includes a cost associated with the walk from parking location to final destination as well as the actual parking fee.

5. The log of employment density (employment per acre) for workplace zones outside the central area.

Workplace attractions are employment at salary levels matching the income quartile of the traveler's household.

The resulting drive alone model calibration has a pseudo r-square statistic of 0.354 relative to a model with zero coefficients (the choice probabilities in a zero coefficient model are proportional to a zone's attractiveness Wj), and all model coefficients are quite significant. This impedance equation was coded into the model and the simulation run for workers in a large sample of households with at least one vehicle per worker. When simulation results were compared against the home interview survey, there were too few short trips simulated and the average simulated drive alone trip length was too long.

The solid line in Figure 5 shows the drive alone trip length frequency by the number of trips in five-minute time intervals from the household travel survey. The trip length frequency for the calibrated model incorporating the above equation for drive alone impedance is the dashed line in the figure. The bias observed in the model results is apparent in the ALOGIT tables. Drive alone trips less than twenty minutes are underestimated, while longer trips tend to be overestimated. These biases exist even though the modeled and surveyed average travel times are nearly the same.

Attempts to improve this drive alone calibration focused on the in-vehicle travel time variable. The above impedance function was replaced with a similar function except that in-vehicle travel time was replaced with the square root of in-vehicle time. Model calibration with this revised impedance function produced the following equation and coefficients:

$$I_{ij} = -0.459 * \sqrt{ivt_{ij}} + 0.258\mathrm{E}-05 * opp_{ij} - 1.592 * op\cos t_{ij} - 0.230 * pk\cos t_j - 0.294 * den_j .$$

The resulting model's trip length frequency is shown in Figure 5 by the shorter dashed line. It more closely matches the home interview's trip length frequency than the original calibrated model. The pseudo r-square statistic for this model calibration was 0.362 relative to a model with zero coefficients and all model coefficients are highly significant.

The fourth trip length frequency distribution shown in Figure 5 is for a drive alone destination choice model with an impedance equation incorporating the log of in-vehicle travel time. The following calibrated model is the result of this formulation of impedance:

$$I_{ij} = -0.940 * \ln(ivt_{ij} + 1.0) + 0.167\mathrm{E}-05 * opp_{ij} - 1.633 * op\cos t_{ij} - 0.262 * pk\cos t_j - 0.311 * den_j .$$

This model has a pseudo r-square value of 0.366, which is only slightly different from the previous calibration. These calibration results point out that destination choice models of widely varying quality can be calibrated with little difference in their pseudo r-square statistics. Other goodness-of-fit statistics, such as time interval root mean square error, may be more useful for destination choice model evaluation.

Vehicle Mode Choice Model Calibration

The vehicle mode choice models in the simulation are similar to conventional logit mode choice models except that the mode is selected for a trip whose destination depends on the mode chosen. The utility of each mode has two components. All mode choice models include a set of modal "logsum" variables that measure the accessibility of attractions via the modes available. The second component of a mode's utility depends on the traveler's household characteristics.

The "logsum" variables are constructed from the denominators of the mode specific destination choice models, and are calculated by the following equation for a particular mode m:

$$L^m = \ln\left(\sum_j W_j \, e^{I_{ij}^m} \right).$$

Figure 6 plots three of these "logsum" variables for walk to transit, drive alone, and drive alone to transit modes for workers in households with at least one vehicle per worker.

The "logsum" values cannot be directly compared since they are scaled differently for the three modes and have separate coefficients in the mode choice utilities. The patterns, however, reflect the employment accessibility offered by the alternative modes. The walk to transit mode does not serve a large portion of the region, while the drive alone "logsum" declines steadily as one moves away from the high employment levels of the central area. The drive alone to transit "logsum" variable traces the radial rail transit and commuter rail corridors in the region. The mode choice models for home – shop trips listed in Table 2 illustrate the calibration results and the type of traveler's household characteristics that are the remaining variables in the mode utilities. Household characteristic variables generally are binary zero-one variables in these models. Pseudo r-squares for the three home – shop models are 0.129 for all persons in households without vehicles, 0.086 for workers in vehicle households, and 0.137 for non-workers in vehicle households. Although these pseudo r-squares may seem low, they are measured relative to a model with constant utilities; a model whose predicted mode choice probabilities are equal to the observed mode choice proportions in the input data. It is difficult to improve upon this reference model when observed mode choices highly favor a single mode, as is the case in the three home - shop models. The APPLY function in ALOGIT was again used to check for biases in the calibrated models. Tables were prepared for each ALOGIT calibration that cross-tabulated the selected and observed mode choices with the number of workers in the household, non-working adults, children, vehicles available and the household's income quartile. Each cell of these tables compares the number of observations in the calibration data set against the values predicted by the model for the same calibration data. These tables served two purposes. They indicated which household characteristics were important during mode choice calibration, and also, the appropriate mode utility equation for the variable. Secondly, the tables helped evaluate whether the calibrated model was biased with respect to one or more household characteristics.

All mode choice models were initially calibrated without bias constants. After reviewing model results, small bias constants were introduced into the mode choice utilities to improve the fit of the models to observed mode choice proportions. The average amount of bias needed by each mode to match observed choice proportions is estimated by taking the logarithm of the ratio of observed to estimated mode share. Two or three iterations of simulation – bias constant estimation were sufficient to accurately match simulated with observed mode shares. Average trip lengths were also compared as bias constants were adjusted to ensure that this effort to improve the mode choice performance of the model did not negatively affect its predicted destination choices.

Figure 7 shows the final simulated and household travel survey trip length frequency for drive alone and walk to transit trips for all workers. There is reasonable agreement between observed and simulated trip lengths, especially when one considers that the household travel survey is less than a one percent sample of households, while the model results shown are for a simulation of ten percent of all households. Average trip lengths for the simulated and observed drive alone work trips are virtually identical, while simulated walk to transit trips average trip lengths are about 0.8 miles less than observed.

Final Comments

The model outlined in this paper demonstrates that it is possible to incorporate a fairly detailed travel simulation into the work program of a Metropolitan Planning Organization without totally disrupting the ongoing technical work of the agency. The model is compatible with commercial software for transportation planning, and reads/writes into databanks that the agency currently supports. The destination choice and mode choice models are calibrated from a conventional travel survey of trips made by households and do not depend on an activity survey. Simulation of individual travelers offers many advantages. Even though the approach taken in this model does not reproduce an individual's daily travel itinerary, the models for travel away from the household take into account the previous mode and destination choices of the traveler. The synthesized household characteristics of the traveler are also available for non-home based travel models. As a result, the model can readily simulate the daily travel of groups of households. For example, all trips made by households in the lowest income quartile can be simulated. This feature enables the analyst to better evaluate the travel needs of particular household types, and also determine the types of households that benefit from or are harmed by facility improvements.

The simulation also allows destination and mode choice models calibrated to individual behavior to be directly used in a model that provides aggregate trip table forecasts. This is extremely advantageous from the point of view of model calibration. All of the models in the simulation do not have to be calibrated at the same time, and individual models can be calibrated to special purpose data sets. The simulation can be updated over time through a series of smaller surveys of different types of households and individuals, market segments that can also be changed in the model with relative ease. The simulation is a flexible shell within which various mode and destination choice models can be evaluated and applied.

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Table 1: Simulated Trip Purposes

Person	TRIP PRODUCTION LOCATION		
	Home	Work	Neither Home Nor Work
Adult Worker	Home – Work	Work – Work	Other – Other
	Home – Shop	Work – Shop	
	Home – Other	Work – Other	
Non-Working Adult	Home – Shop		Other – Other
	Home - Other		
Non-Driver Child	Home – Non-home		

Table 2: Mode Choice Calibration for Home – Shop Trips

	Households Without Vehicles				Workers in Vehicle Households						Non-Workers in Vehicle Households					
	Walk to Transit		Ride Share		Walk to Transit		Drive Alone		Ride Share		Walk to Transit		Drive Alone		Ride Share	
Variable	Value	"T"	Value	"T"	Value	"T"	Value	"T"	Value	"T"	Value	"T"	Value	"T"	Value	"T"
Mode "Logsums"																
Walk to Transit	0.908	67.7			0.387	41.9					1.095	98.8				
Drive Alone							1.056	119.3					1.191	112.5		
Ride Share			0.564	38.3					0.933	117.5					1.266	128.2
Walk Time to Transit	-0.037	-7.9			-0.046	-21.3					-0.163	-56.7				
Household Size																
One Person (0,1)							1.880	143.4			1.592	60.7	2.916	199.4		
Three Plus Persons (0,1)									0.552	75.3					0.837	107.9
Workers in Household																
One or More (0,1)			0.469	24.8									0.584	78.9		
Two or More (0,1)			1.403	42.6							2.575	183.6				
Three or More (0,1)					2.089	116.5	0.318	48.5								
Non-Workers in Household																
Two or More (0,1)	0.421	20.7														
Children in Household																
None (0,1)							0.275	45.3					0.501	73.4		
One or More (0,1)	2.118	62.7														
Vehicles in Household																
One (0,1)					1.750	92.0										
Two or More (0,1)							0.431	68.0					0.604	94.2		
Household Income																
Lowest Quartile (0,1)					0.686	39.0					1.576	115.3			0.576	83.5
Highest Quartile (0,1)			2.445	32.8			0.422	82.4					0.277	42.3		

FIGURE 1 Non-Motor and Vehicle Zones

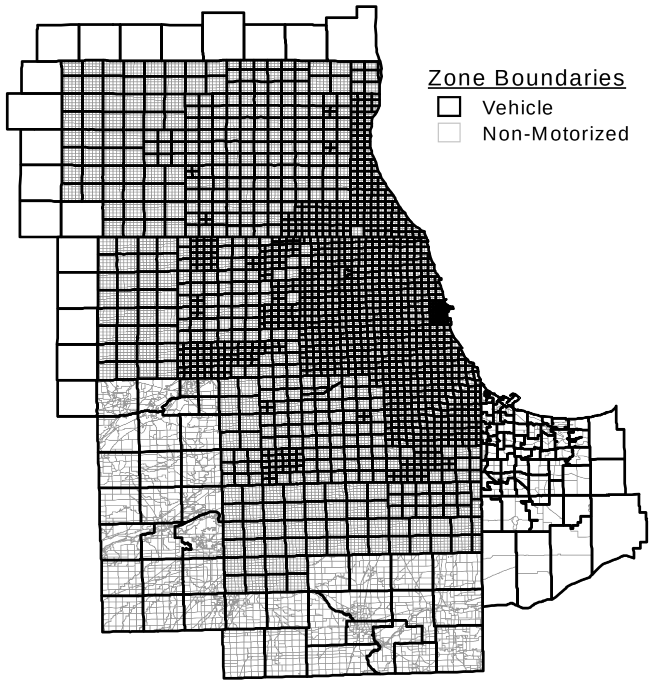


FIGURE 2 Regional Simulation Model Logic

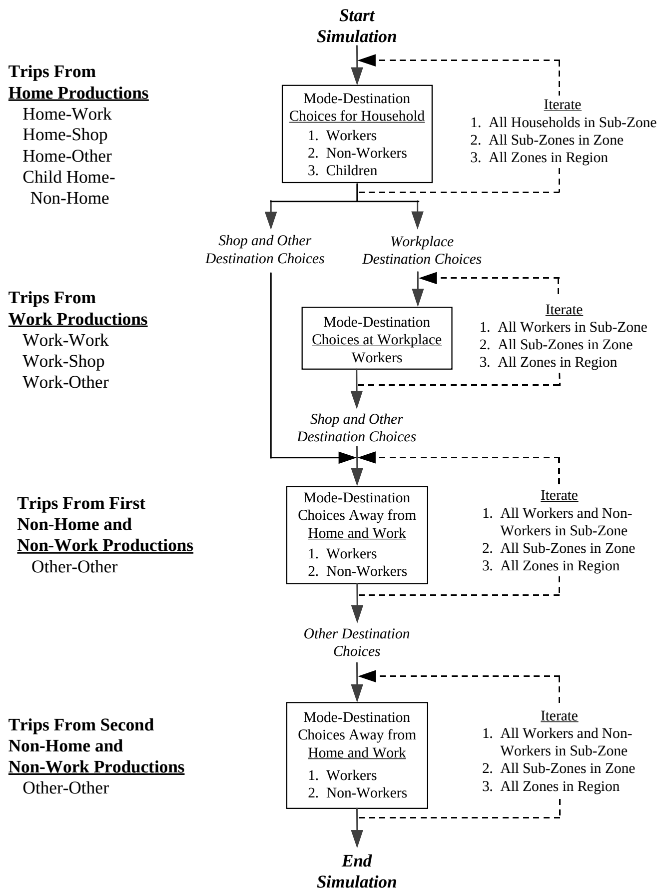


FIGURE 3 Simulated Trip Pattern

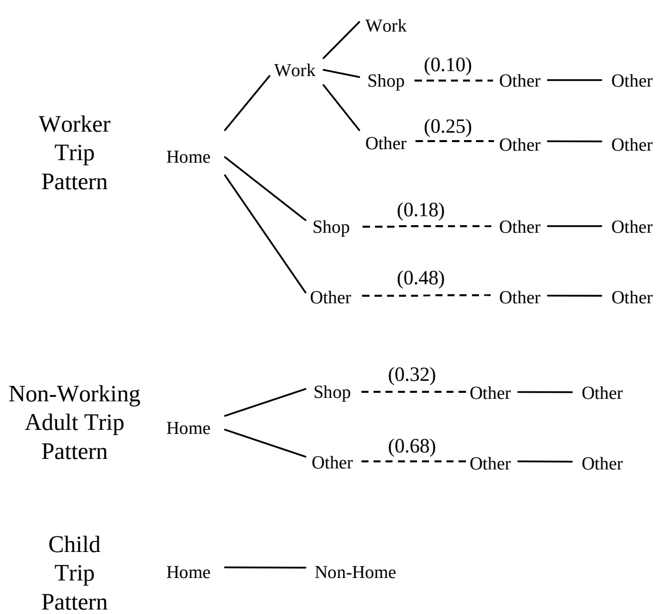


FIGURE 4 Home – Work Destination and Mode Choice for Workers With Vehicles

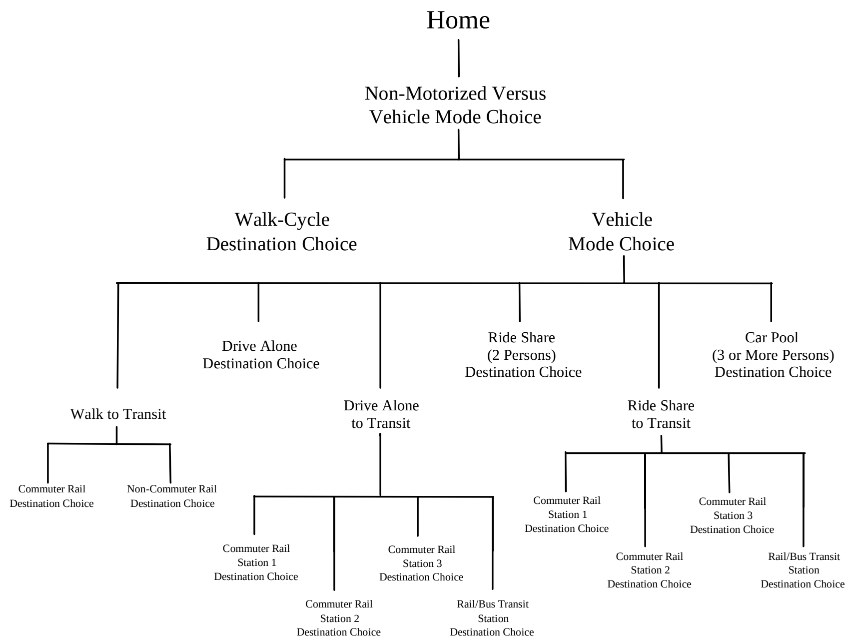


FIGURE 5 Work Trip Length Frequencies

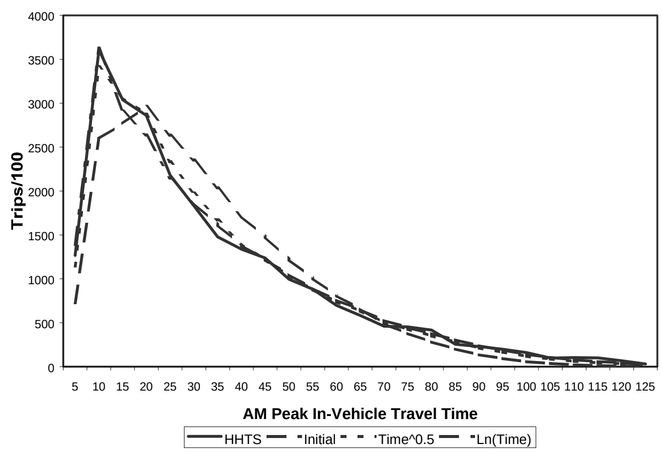
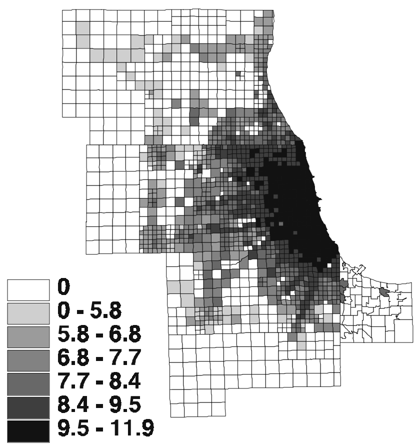
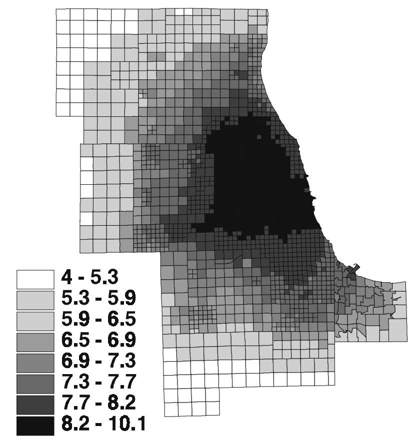


Figure 6: Home-to-Work “Logsums” for Workers: High Vehicle Ownership Households

a. Walk to Transit



b. Drive Alone



c. Drive Alone to Transit

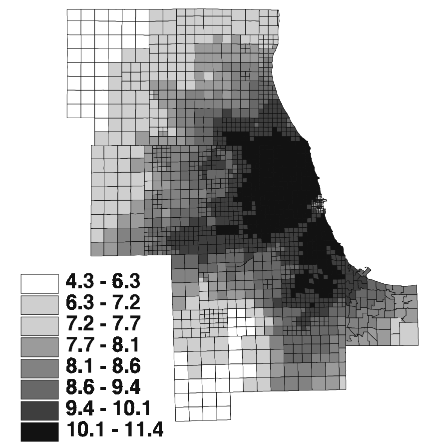
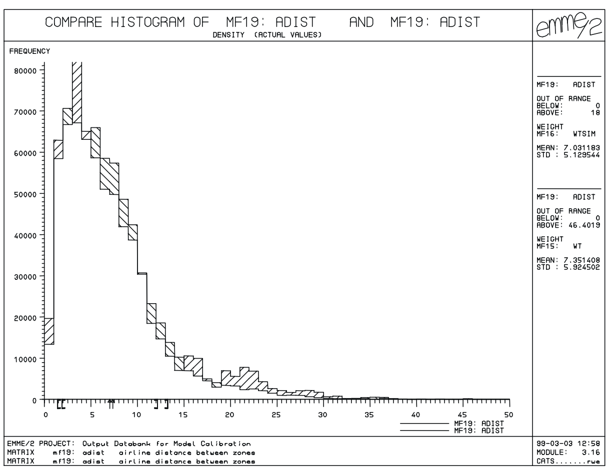
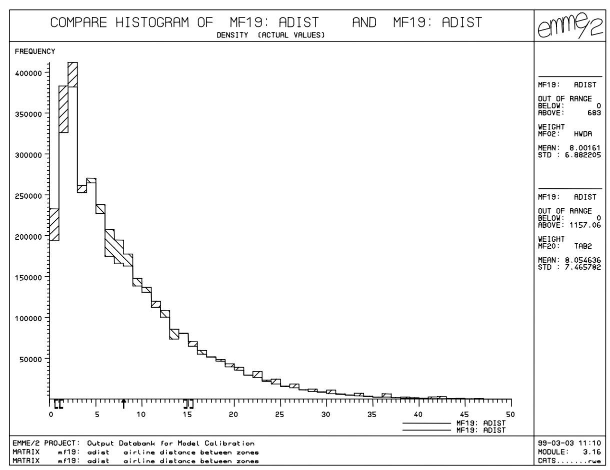


Figure 7: Simulated and Household Travel Survey Home – Work Trip Lengths

a. Walk to transit



b. Drive Alone



Forecasting Inter-Community Travel in Southeast Alaska

Susan Hendricks, *KJS Associates*; and Jeff Ottesen,
Alaska Department of Transportation and Public Facilities

Abstract

The Alaska Department of Transportation and Public Facilities prepared a transportation plan to determine the most cost-effective way to meet short- and long-term transportation needs for the Southeast Alaska region. The unique geography of the region presents many transportation challenges; travel between communities in Southeast Alaska and to areas outside the region is dependent on ferries and airplanes. The Alaska Marine Highway System (established in 1963, following Alaska's statehood) provides access for commerce, education, medical care and a wide variety of personal and commercial travel purposes. It is the primary means of moving vehicles (personal, tourist and commercial) into and out of Southeast communities.

The transportation plan needed to identify the best places in which to make major transportation system investments and to assess tradeoffs and impacts of the various investment choices. To meet these objectives, a multi-modal travel demand model was developed for the region. The travel forecasts are used to assess the growth in demand for transportation (for people, goods and vehicles) between communities over time; estimate the origin and destination patterns of travel throughout the region; evaluate travel demand by mode (public and private ferry, air, roadway) based on travel service parameters for the alternatives; assess the potential for induced travel demand generated by new transportation facilities and services; and evaluate the impacts of system supply constraints on travel demand.

The modeling approach is a modification of a direct demand model that is typically used to forecast inter-urban travel. It simultaneously estimates trip generation, trip distribution and mode choice based on the population size and socioeconomic characteristics of the community producing the trips, the opportunities existing at the destination, and the travel characteristics (travel time, frequency and cost) between the communities for each available mode. The model parameters were estimated using a travel survey of SE Alaska residents, which collected data on household characteristics and travel patterns.

Calibration Of Travel Demand Models For Small Jurisdictions - Our Standards Are Way Too Low

Matthew J. Henry, P.E. and Winnie Chung, P.E., *Fehr & Peers Associates, Inc.*

Abstract

Historically, travel demand models have been developed for highly urbanized areas. As demand models become more commonplace, many smaller jurisdictions have been developing and utilizing travel demand models as well. The models are typically calibrated to a base year in accordance with the validation standards for acceptable model error as set forth in documents such as Travel Demand Forecasting Guidelines, Caltrans, November 1992. This particular document includes a set of statistical standards for measuring model error. For one set of standards, the criteria is such that the maximum deviation between a model volume and an actual traffic count on any given link is inversely weighted according to the total volume of traffic on that link. In other words, roadways with high traffic volumes are allowed a small deviation, whereas roadways with low volumes are allowed a high deviation.

Unfortunately, these standards are weighted such that a high level of model error is considered acceptable in demand models for smaller communities because the traffic volumes on most of their roadways are fairly low. The authors of this paper have developed travel demand models for several small jurisdictions including:

- Amador County (29,600 population),
- Calaveras County (38,700 population),
- City of Woodland (42,500 population), and
- City of Dixon (13,100 population).

Based on this experience, the authors believe that data is available to calibrate demand models for smaller communities to a much higher standard than is currently considered acceptable. This paper will describe the experiences of these and other model calibration efforts for smaller jurisdictions and will culminate in specific recommendations for higher standards of acceptable model error.

So – You Want to Calibrate an Activity-Tour Based Model?

T. Keith Lawton and Richard Walker, *Portland METRO*,
and Mark Bradley, *Bradley Research and Consulting, Inc.*

Abstract

METRO, in Portland, Oregon, has an estimated activity-scheduling and tour-based model. It is a model that is a nested logit (partially sequential and partially simultaneous) ranging from primary mode and destination choice up through time of day to daily activity pattern by tour type. It has non-nested choice of intermediate stop locations, and mode and destination choice for work-based sub-tours.

Previous models of this type (Stockholm and the Netherlands) have been applied using a pivoting approach, which avoids some calibration issues.

This presentation will discuss the two-stage calibration of this model for practical application in Portland (calibration to match the travel and activity survey, followed by calibration to match ground counts, transit passenger counts and parking accumulation counts). There is much difficulty when the assignment used to match "ground truth" is trip based, following a decomposition to trips from the tours, and the unit of generation and analysis for modeling is the activity pattern arranged into tours. This will be a discussion of a process that is, of necessity, less precise in terms of matching "ground truth."

Calibrating a Statewide Land-Use Transport Model of Oregon

Patrick J. Costinett and Rick Donnelly, *Parsons Brinckerhoff Quade & Douglas, Inc*.;
William J. Upton, *Oregon Department of Transportation*; and
J. Douglas Hunt, *University of Calgary*

Abstract

A land use transportation interaction model of the entire state of Oregon has been developed using the TRANUS framework. This has been done as part of a project sponsored by the Oregon Department of Transportation to develop land use and transport analysis tools, which is consistent with relevant directives in ISTEA. The result is a spatially disaggregated input-output representation of the Oregon economy, with distributions and interactions of employment and population influenced by transport disutilities and by market-clearing prices for land determined endogenously at each of a series of points in time. Transport demands arise from economic interactions and are loaded to network representations using a combined treatment of mode split and assignment with path enumeration and multi-path allocation.

A major part of the effort to develop a model using the TRANUS framework is in the calibration of the model. This involves the identification of suitable observed 'targets' and the search for a set of model parameters that provides a satisfactory model fit to these targets. The complexity and fully-integrated structure of the TRANUS framework make the search for model parameters a labor-intensive, iterative, sequential process.

In the case of the Oregon model, its spatial distribution function parameters were calibrated using targets based on 1990 (base year) trip length frequency distributions for freight by industrial sector and passenger travel demand by trip purpose. Extensive roadside and household surveys were conducted to provide appropriate observed values. Further adjustments were made considering the fit of the model temporal dynamics over the period from 1990-1995. The model's travel demand function parameters were calibrated using targets based on transport flows for both freight and passenger modes.

The explicit representation of interactions between land use and transport means that changes made to the spatial distribution functions also influence the fit to the transport-related targets, and that changes to the travel demand functions also influence the fit to the land-use-related targets. This is what adds so much complexity and makes the calibration task so labor-intensive. The use of a carefully programmed process throughout the entire calibration task becomes very important as a result.

This paper describes various aspects of the approach used in the calibration in this first statewide application of the TRANUS framework in the United States - including design considerations, data inputs and search techniques - and it indicates the results obtained. It also offers conclusions about both process and results, and considers implications relevant for other future similar work.

An Integrated Land Use And Transport Model For The City Of Swindon

Tomas de la Barra, F. Brown, P. Rickaby, J. Turner, P. Steadman

Abstract

This paper describes the application of an integrated land-use and transport model to the city of Swindon, UK, carried out by a team from the Open University, Manchester University, RTA Associates and Modelistica. The EPSRC supported this work, as part of a broader program called 'Sustainable Cities'. The purpose of the study was to assess the effects of alternative land use-transport policies on a medium-size city, with emphasis on welfare and energy consumption. The TRANUS integrated model was calibrated to Swindon for the base year, and projections were made into the future assuming alternative land use and transport policies. This was complemented with an evaluation procedure to assess the economic and environmental effects of the alternative policies.

The paper begins with a description of the structure of the model, which included detailed representations of the transport system, the location of activities and the real estate system. The transport system was represented in terms of a multi-modal network, with low and high occupancy cars, buses, passenger rail, pedestrians and bicycles, with park-and-ride and bike-and-ride. Other transport policies were bus-only lanes, parking restrictions and car-ban in the town center. A detailed energy-accounting system estimated the energy used by vehicles of different types as a function of speed.

The land use model represented the relationships between the location of activities and consumption of floorspace and land. Activities were classified into several types of employment and households. Several types of floorspace were defined, as well as several types of land. The model simulated the location of activities and the choice between the different building types, and in turn, floorspace types were assumed to choose between alternative land types. A market-clearing algorithm was used to simulate equilibrium prices for each type of floorspace and land. When projected into the future, the model simulated changes in prices, urban area expansion, land use changes and demolitions. Energy consumption functions were estimated and applied to each type of floorspace. The results of the model are presented next, making emphasis on the effects of the alternative policies on activity location, travel behavior and energy consumption. Four alternative scenarios were tested, each one assuming a combination of land use and transport policies. The first scenario represented a trend case. A second scenario represented a compact-city approach with strong transport policies to encourage public transport. A third scenario allowed limited expansion of the urban area, with less forceful transport policies. A fourth scenario represented the opposite of the compact-city scenario, directed towards the surrounding villages, coupled with public transport corridors.

A final section of the paper presents a number of conclusions and identifies areas for future research. The main conclusion challenges the view that there is an ideal urban form that minimizes environmental impacts and benefits activities. It is argued that each case must be studied individually and the use of integrated models of the kind presented in this paper must be used to arrive at an optimized set of policies.

Essentials for Transit-Oriented Development Planning: Analysis of Non-Work Activity Patterns and a Method for Predicting Success

Dick Nelson, *Integrated Transport Research*; and John Niles, *Global Telematics*

Abstract

One hoped for benefit of transit-oriented development (TOD) is that a mix of shopping, service, and recreation activities at urban centers linked together by high quality transit will induce citizens to drive less and walk or ride transit more. Consequently, the success of the TOD concept depends greatly on the response of developers, consumers, and taxpayers to the new land use-transportation configuration.

Developers and owners of establishments that provide goods and services are expected to depart from highly independent siting criteria that now either result in large clusters of retail activity or cause stores to occupy stand alone sites, both with high levels of drive-to access. Consumers are expected to choose activities that are within close proximity rather than from among the great variety available in the regional marketplace. And taxpayers are expected to fund much greater levels of transit service needed to support the new land use patterns and induce significant numbers of new transit riders.

Efforts to predict the success of TOD would benefit from a much better understanding of nonwork activity patterns and trends on a metropolitan or travel corridor scale. Of the sixteen factors that will contribute to success on a regional scale, only a few are crucial at the local or station-area level, where more professional attention to success factors is observable.

A review of current evaluation methodologies that have been applied to TOD indicates that all have limitations. Travel demand modeling, in particular, cannot accurately predict the response of the marketplace to major transportation and land use changes. The authors outline a new approach to evaluating the likely success of TOD. This approach, termed *Backcasting Delphi*, is an exercise that pulls in critical thinking from key stakeholders, analysts, and planners. It starts with the desired TOD future and attempts to predict the circumstances needed for it to be realized, and whether those circumstances are achievable, given the forces shaping urban retail structure.

Introduction

Transit-Oriented Development (TOD) has rapidly emerged as the central urban planning paradigm in the United States. Leaders in many metro areas have made, or are contemplating, major investments in new rail transit capacity, under the assumption that synergy between compact, mixed-use development and mass transit will change auto-dependent growth and travel patterns (*1*).

From an economic perspective, success of TOD will depend on the benefits -- both societal and personal -- it produces relative to its costs (Table 1). The public may experience benefits in the form of congestion reduction and air quality improvements. To the extent that TOD reduces excessive infrastructure costs associated with dispersed development, these would be accounted as secondary public benefits. The principal personal benefits may be travel time and expense saved, in addition to reduced congestion time. Personal benefits also include the possibility that some households can reduce the number of cars they own and operate. Other benefits, of a social nature and more difficult to quantify, may be associated with the enhanced quality of living TOD is believed to produce (*2*).

Public costs are primarily the transit capital and operating costs. The cost of housing in proximity to stations may be higher. Other direct costs may arise. To the extent that increased density does not result in reduced travel, congestion mitigation measures may be required. There may also be costs associated with TOD planning and any public incentives that may be needed.

In the context of planning, success of TOD depends on the response of developers, consumers, and taxpayers to the concept and to the public strategies that encourage it. Niles and Nelson (*3*) have identified 16 factors that will determine success at the regional or transit corridor level (Table 2). Fewer factors will control success at a single station-area, a main focus for planners to date.

The success of TOD is not without considerable obstacles (*4*). Growing wealth and technological innovation has lead to a very rich and diverse retail marketplace, which in turn generates increasing numbers of trips for nonwork purposes. Table 3 lists the retail trends that are readily observable in major US metro areas. Travel for nonwork purposes now constitutes 4 of 5 trips, and many commute trips involve stops for nonwork activities.

These trends, the result of powerful forces operating in the consumer marketplace, constitute a significant challenge to TOD planners. Figure 1 attempts to describe schematically the situation. Stated as a question, the problem is: Can major transit investments, together with policies encouraging development near transit stations, sufficiently offset the behavior generated by expanding consumer income and preferences, as well as by market and technological innovation, to produce benefits commensurate with costs?

Decision Tools for Determining the Success of TOD

In order to estimate the likelihood of success, planners are faced with determining the travel impacts of TOD on a regional scale when there is no existing example from which to learn. This is really a sub category of the general problem of estimating the effect of land use policies on travel patterns. Handy (*5*) has reviewed and critiqued alternative approaches used to explore the link between urban form and travel behavior, so we do not cover these efforts here. Instead, we look at methods that have been used to predict the success of TOD, and in particular, how well they deal with the strong effect of nonwork activities.

Predicting the success of TOD is made difficult by the large number of variables that must be taken into account. As the factors in Table 3 suggest, regional success of TOD is determined at three general levels: 1) the available public resources that limit the number of TOD stations and the quality of the transit service, 2) the response of developers and store owners to the market opportunities associated with TOD locations, and 3) the change in travel behavior of consumers in response to the activities available at TODs. Each interacts with the others. All, separate or together, must be amenable to analysis if the decision making process is to be adequately informed. And the ultimate challenge, when regional success is at question, is to choose tools that can assist the process even when there exists no operational regional TOD network to provide empirical data that establish the functional relationship between a factor and change in travel patterns.

Table 4 lists some of the decision-supporting methodologies that have been applied to TOD planning and the more general topic of New Urbanism in approximate order of their increasing complexity. Each of the methods has both advantages and limitations that will be briefly discussed, along with selected instances where each method has been applied. This list is not meant to be exhaustive of either the tools that are available or their real-world applications. The list is simply intended to show that a range of methods are available to help planners and decision makers ascertain the likely success of TOD.

Structured Discussion

Clearly the simplest method, structured discussion might merely be a roundtable discussion involving professionals, both practitioners and academics, who are involved in TOD and related issues. Although lacking in comprehensiveness and analytical component, it can yield useful insights, especially if the discussion is summarized and salient points are reported to the broader community of stakeholders. In 1994, *Berkeley Planning Journal* assembled eight planning professionals and scholars for a discussion of New Urbanism. Participants were asked to read at least two of four influential books and a recent critique. An abridged transcript was published by the Journal (*6*).

Visual Simulation

Since there are few contemporary examples of TODs that have textbook design features, it is difficult to gauge potential market demand, and this may be a factor in deterring TOD development activity. The concern is that consumers are reluctant to embrace what they have not experienced. To get around this obstacle, Cervero and Bosselmann (*7*) created photo images of "transit villages" with different densities and amenity mixes. They used these computer-generated simulations to query a representative sample of San Francisco Bay area residents as to their preferred neighborhood. Although an individual's response to the look of a hypothetical neighborhood cannot possibly encompass all of the factors that determine actual home selection preference, it can suggest to developers and policy makers density and design alternatives that may not have been fully tested or may even be disallowed under existing land use regulations.

Case Studies

Even though TOD experience is limited, case studies can reveal factors that control the real-world form of TOD and the speed at which it can be implemented. Boarnet and Compin (*8*) used interviews and a review of zoning codes and planning documents to ascertain how localities in San Diego County planned for and implemented TOD. They were able to draw conclusions as to the role of local interests versus regional interests and the time frame for benefits to be realized, information that might be generalized to other urban areas considering TOD and rail systems. A case study will not determine whether TOD will succeed in other urban areas, but it can help identify general issues beyond the factors in Table 2 that may support or limit success.

Transit Cost and Performance Estimate

Downs (*9*) employed a simple but straight forward approach to determine the performance of TOD by estimating the number of TOD centers, assuming their density and size, that would be required to accommodate the growth of a hypothetical metropolitan region over a 10 year period. Downs used the average population and employment growth during the 1980's of metropolitan areas that had achieved a 1990 population of one million or more. This allowed him to infer the number of transit stations and the financial feasibility of the regional transit system needed to support TOD. Luscher (*10*) used a similar approach to analyze the impact of TODs on auto travel in the San Francisco Bay area. He was able to estimate the reduction of regional per capita VMT TOD would produce, and to draw conclusions regarding its appropriateness as a regional congestion management strategy. Although such cursory methods can provide an important perspective on the tradeoff between transit system cost and transportation performance of TOD on a regional scale, they may not yield a clear indication whether success is possible at a corridor level, especially where there is opportunity for redevelopment and infill.

Sketch Modeling

In order to reduce the effort required for traditional demand modeling of TOD (see below), Bowlby and Fox (*11*) created a sketch planning tool. Essentially an abbreviated version of the regional demand model, the procedure allowed the transportation and air quality benefits of several TOD "packages" involving different levels of land use change, transit service improvement, and parking management for Memphis, Tennessee, to be evaluated. The tool permitted conclusions to be reached as to whether desired performance measures, including cost effectiveness measures, would be met. As discussed below, this method, while simplifying the analytic problems, necessarily suffers from the same difficulties all methods using regional travel demand forecasting models will encounter when applied to TOD.

Four-Step Modeling - Simulations

A similar but somewhat more complicated approach is to use a travel demand model for the simulation of regional or corridor TOD performance, providing land use inputs in the form of various plausible scenarios for residential and employment growth concentrations. Thompson and Audirac (*12*) did this for a Sacramento corridor, assuming that 105,00 more people and 52,000 more jobs would be distributed among urban TODs, neighborhood TODs, the central business district, and the urban fringe in differing amount. They estimated how transit mode choice and ridership for residents and commuters would be affected under each of four assumed scenarios. They were also able to draw conclusions about the most effective design of TODs, particularly the concentration of employment versus housing.

Four-Step Modeling - Real Growth Estimates

Metropolitan regions typically employ travel demand models to predict transportation system performance and air quality for expected land use scenarios. Land use changes are usually input assumptions to the models. In the case of the central Puget Sound region, planners assumed that a portion of new housing and employment will be concentrated in 21 designated urban centers as a result of regional growth management and transportation strategies (*13*). These are educated guesses by planners familiar with local development patterns and, at best, can provide rough estimates of the real transportation system performance of TOD as determined by market forces and government policies.

The limitations of traditional travel demand modeling in applications that involve forecasting the long-range travel changes resulting from nonwork activities associated with TOD are significant (*14, 15*). Data for locational attributes - prices, quality, and variety of goods at different shopping locations -- needed to specify consumer utility is lacking. Modeling studies of store location and consumer behavior dynamics have been few. And without previous experience with regional TOD networks, empirical data is scant that would allow calibration of models even if they were accurately specified. These same limitations will also hinder the application of activity-based modeling, which some believe will eventually replace four-step demand models.

Recommended TOD Decision-Informing Process: Backcasting Delphi

The evaluation methods just reviewed assist but do not offer full and convincing guidance on the difficult question of how to plan TOD on a regional or corridor scale such that the benefits justify the necessarily large investment in transit infrastructure and operations. There is a clear need for a new planning approach that more directly matches the difficulty of the problem. A new tool is required that takes into account the complexity of the metropolitan retail structure -- a structure that will continue to evolve dynamically. It should employ available descriptive data and information, yet it should not demand that only quantitative results be relied upon for estimating the likely impacts of TOD.

We believe a method that can meet these requirements is **Backcasting Delphi**, which melds the older approach of using diverse expert opinion to reach consensus through an iterative process (**Delphi study**) with the newer approach of working back from the desired outcome to determine the necessary policies and other inputs that will produce that outcome (**Backcasting**). See the following box for a description of Backcasting by one of it inventors.

Backcasting and Delphi have been applied separately and together to energy and transportation forecasting, principally in Europe and Canada. Hojer (*16*) used Backcasting Delphi to study the impacts of transport telematics under three passenger transportation scenarios: improved road system with user fees, improved public transit through rider information, and dual mode system which combines the flexibility of the private car with the capacity of public transport (private vehicles operate both on and off automatic guideways).

Backcasting:

Backcasting's concern is not with what futures are likely to happen, but with how desirable futures can be attained. It involves working backward from a particular desirable future endpoint to determine the physical feasibility of that future and what policy measures would be required to reach it. Targets are continually revised as new knowledge is acquired.

- Karl Dreborg, Essence of Backcasting, *Futures* 28(9), 1996, pp. 813-828.

As adapted and applied to TOD, Backcasting Delphi would utilize a multidisciplinary panel that includes urban planners, architects, urban geographers, urban economists, commercial developers, store site selection managers, transportation planners, and environmental organization representatives. Before undertaking the evaluation, they would specify the problem and establish the purposes, goals, objectives, boundaries, and other important parameters of the evaluation exercise. Table 5 briefly describes specific steps in the process that might then ensue.

For the purpose of TOD evaluation, Backcasting Delphi provides several advantages over other methods. In the ideal case, it would precede decisions to invest in transit capacity. It would allow involvement of a broader range of expertise than is normally the case in transportation and land use planning. For example, retail industry site selection managers would have equal status with regional transportation planners. Most if not all of the significant forces shaping urban form would be considered. It would allow the setting of a planning horizon that reflects the uncertainty inherent in these forces. The land use-transportation scenarios evaluated would not be limited to the regional planning vision and to no-build and build transportation alternatives. Through the iterative process, others would be considered until consensus is reached on a feasible scenario that is compatible with the forces shaping the urban environment. With a multi-disciplinary Delphi panel, broader social equity questions would also likely be considered, as well as a range of opportunity costs.

The process can be open to the public in ways that modeling cannot be. The empirical data, estimates, and assumptions would be available for public inspection. A report might be issued after each step, which would allow stakeholders, including elected officials, the opportunity to provide feedback throughout the effort. Information considered and techniques used would be transferable across regions. A Backcasting Delphi exercise could be executed nationally as well as regionally.

Conclusions

The complex and every-evolving retail structure of the American economy requires that a new method for the evaluation of TOD success be designed and implemented. The method must allow for consideration of the many factors that will determine the transportation and related benefits of compact, mixed-use development. A new method, Backcasting Delphi, which brings together a wide range of expertise and promotes consensus on feasible scenarios, is a possible candidate. It could be a valuable tool in TOD planning and policy-making.

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Table 1: Simplified TOD cost-benefit accounting.

Costs	Benefits
• Transit system construction • Transit system operations • Mitigation of traffic congestion caused by compact development • Station-area housing cost premium • TOD planning • Public incentives to developers	• Congestion reduction lowering time delays and fuel consumption • Air quality improvement reducing health costs • Reduced infrastructure • Personal travel time savings • Vehicle operation savings • Personal vehicle ownership reduction

Table 2: Factors determining the success of TOD.

Factor	Station area success	Regional success
Number and siting of TODs (station areas)		X
Transit quality		X
Transit technology		X
Street pattern	X	X
Station area parking	X	X
Employment and housing density	X	X
Commercial mix	X	X
Retail siting criteria		X
Regional market structure		X
Consumer activity patterns		X
Travel behavior/trip chaining		X
Zoning flexibility/land assembly	X	X
Resident reactions	X	X
Housing type preference/life style & life stage		X
Self-selection in residential choice	X	X
Government policies		X

Table 3: Key retail trends.

Retail activity increasingly polycentric and dispersed
Planned shopping centers dominate market
Smaller malls cluster around major malls
“Big Boxes” market share growing
“Super” stores growing in kind and number
Many chains prefer stand alone sites
Dining out continues strong
Drive to and through convenience growing

Table 4: Examples of decision-support methods that have been applied to TOD and New Urbanism.

Method	Selected application/reference
Structured discussion	Berkeley Planning Journal (*6*)
Visual simulation	Cervero & Bosselmann (*7*)
Metro area case study (interviews, field inspection)	Boarnet & Compin (*8*)
Economic estimation	Downs (*9*); Luscher (*10*)
Sketch planning	Fox & Bowlby (*11*)
Travel demand modeling - assumed growth scenarios	Thompson & Audirac (*12*)
Travel demand modeling - estimated real growth	Puget Sound Regional Council (*13*)

Table 5: How Backcasting Delphi might be used to predict the metro-wide success of TOD.

Step	Scope
Describe present retail structure/patterns	Present urban structure including retail market, travel patterns, past trends
Identify forces shaping urban form	Understanding and subjective weighting of forces: economic, environmental, social, technological. Focus on current and future market trends: commercial development, consumer behavior, nonwork travel patterns
Specify TOD scenario	Likely station-area locations and types (residential, retail, employment, mixed)
Specify transit system	Size and quality of transit afforded under fiscal constraints
Define success	Economic, societal, personal, and environmental benefits and costs; elaborate 16 planning factors; establish planning horizon
Evaluate success	Identification of constraints and supporting policies to achieve feasibility; adaption to new knowledge & consideration of alternative solutions as needed

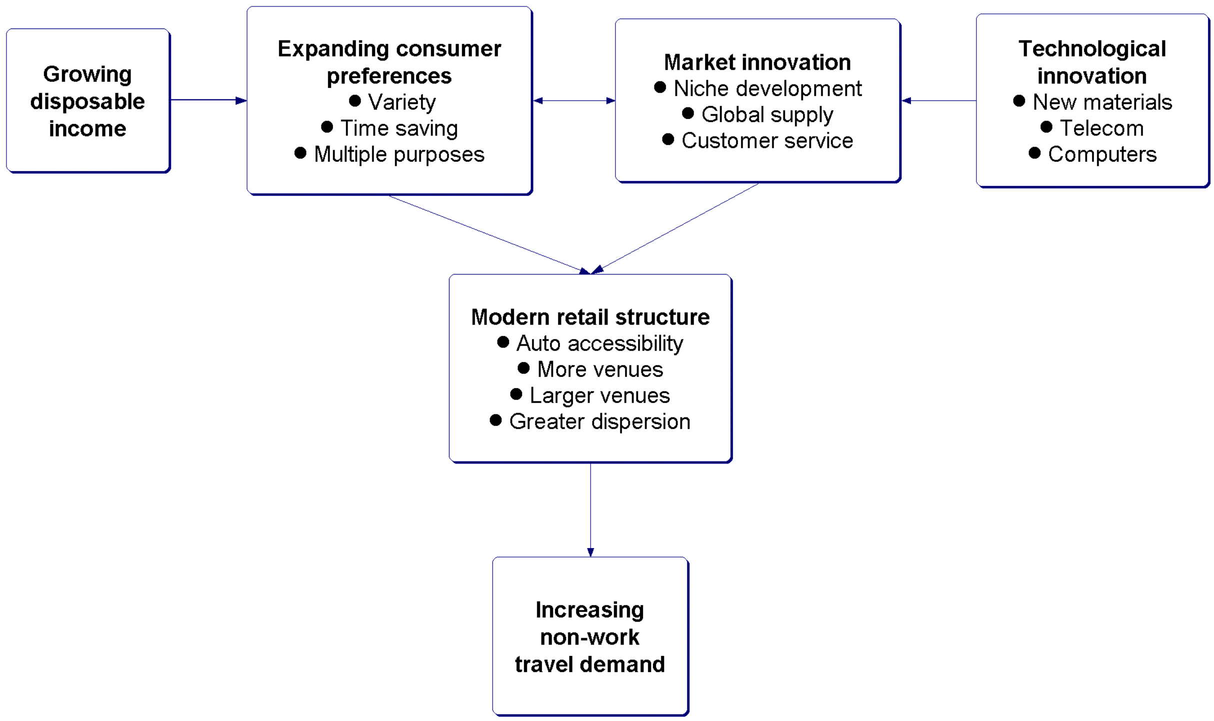

Figure 1: Dynamics of Retail Structure and Nonwork Travel

Land Use, Ridership, and GIS in Transit Decision Making

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Abstract

The presentation/paper will focus on the process where Land Use data is being used to inform the development of alternatives for the Urban Ring Major Investment Study currently underway by the MBTA. This will include the use of the Land Use data and the evaluation of relationships for different alignment possibilities with a Geographic Information System. These evaluation results will be included with the more typical ridership and cost analysis to determine the final alignment recommendations.

The Urban Ring project includes a 14 mile long, 1 mile wide transportation corridor that circles Boston. A similar transportation corridor was identified in the early 1970's as a crosstown route for an innerbelt highway. This project was abandoned when anti-urban highway sentiments in Boston stopped this and other major highway projects.

The need for crosstown transportation still exists and the Urban Ring was proposed to circle Boston with a new transit system. Early on, this project was also recognized as having high potential as a catalyst for economic growth. The project would serve portions of the 6 Cities and Towns through which it passes that have poor transit access and suffer from existing roadway congestion.

The presentation will describe the process which the economic potential and other project goals were evaluated for this project. The process includes the development of the data base, the alignment alternative development process, the use of GIS to compile the relationship to anticipated growth in employment, population, and demographic target areas, and the focused accessibility studies done for target congestion sites. The presentation will also follow the results of the evaluation through the public process that will result in the definition of the final alternatives that will be the product of the Urban Ring Major Investment Study expected to be complete in February 1999.

The presentation will include subsequent applications developed since the Land Use/GIS/Regional Transportation Model relationships were developed. These are expected to include the development of current and future trucking needs and the process where these needs are being used for truck route and freight facility planning.

Calibrating the Temporal Dynamics of the Eugene-Springfield UrbanSim Model

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Abstract

UrbanSim is a general framework for modeling urban land use-transportation interactions. It includes representation of the evolution of the urban system over time using a series of one-year steps. In each of these one-year steps, building floorspace in various categories is developed or redeveloped and both population and employment activities are located or relocated in response to land prices, developer costs and travel conditions established in the previous time step.

A model of the Eugene-Springfield urban area in Oregon has been developed using the UrbanSim framework in work sponsored by the Oregon Department of Transportation. This includes the first calibration of the model temporal dynamics, where relevant functional forms and parameter values are selected for the model components performing these functions. The specific tasks undertaken in performing this calibration are: design of the calibration process, development of relevant goodness-of-fit measures, identification and collection of relevant observations providing calibration target values, search for function forms and parameters, and evaluation of results–all reflecting practical constraints regarding resources and data availability. The resulting calibrated representation of urban temporal dynamics allows evaluation of both the calibration strategy, and the UrbanSim framework and models developed using it.

Integrated Urban Models: Improving the State-of-the-Practice

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Abstract

Based on a recent TCRP study which both examined the state of the art of integrated land-use - transportation models and recommended a comprehensive R&D program for the long-run improvements of these models, this paper discusses short-run, practical steps which MPOs, State DOTs, and others can take to improve their integrated urban modeling capabilities. The paper defines a taxonomy of current modeling practice, then discusses a number of "development paths" from current to improved practice. Issues include: the need for integrated urban models in support of transportation planning; the role of base data; barriers to model development; the relationship between good travel demand models and good integrated models; institutional issues in model development; and, evolutionary strategies for model improvement and deployment.

Introduction

This paper outlines short-run, practical steps for MPOs, State DOTs and others to improve their capabilities in *integrated urban modeling*. These models combine *land-use models*, which forecast land-use (i.e., human activities), with *travel demand forecasting models*, which predict travel patterns on a transportation network as a function of the aforementioned human activities.

The integration provides a feedback mechanism between the two models. The feedback recognizes that land-uses (more specifically, human activities and *choices*) influence travel behavior and the shape of the transportation network, which ultimately influences the distribution and magnitude of different land-uses and, it follows, urban form.

This paper reports some of the findings of a recent study: TCRP Project H-12, *Integrated Urban Models for Simulation of Transit and Land-Use Policies*. The study's main product was the specification of an "ideal" integrated modeling framework. To develop the ideal model, the study proposed a two-part approach:

- A long-run R&D program to address fundamental methodological issues and needs.

- A short-run series of actions, which is the subject of this paper and which had two purposes: develop a base for the long-run R&D program, and initiate / upgrade the current state-of-the-practice. These short-run actions thus provide the "bridge" to move forward both practice and research in the medium-term.

The paper proceeds as follows: Section 2 outlines the case for integrated models in transportation and land-use planning. Section 3 provides an overview of the state-of-the-future;

i.e., the "ideal" model. A taxonomy of capabilities, which is used to guide the evolution of the state-of-the-practice, is presented in Section 4. This serves as the basis for Section 5, which outlines short-run improvements for improving the state-of-the-practice. Section 6 closes the paper with a brief summary.

Why Integrated Models?

The current interest in integrated models is motivated by three factors:

i. *Recognition that while transportation and land-use are strongly related, the current means of analyzing this relationship are limited*. This was found to be true particularly with the transit - land-use interaction.

ii. *Legislative requirements to achieve air quality standards*, which require a proper understanding (and, therefore, representation) of both the land-use - transportation - air quality chain and the role that transit can play as an alternative to the auto; as evidenced by TEA-21 (and its predecessor, ISTEA) and the 1990 CAAA. ISTEA specifically required transportation plans to be coordinated and consistent with land-use plans. TEA-21 maintains this linkage, albeit in somewhat broader terms.

iii. *Fundamental restructuring of the process of travel demand forecasting*, as evidenced through TMIP (the *Travel Model Improvement Program*). Through Track E of its six-part program, TMIP recognizes that an updated treatment of the land-use - transportation interaction is essential in being able to simulate both travel demand and, ultimately, vehicle emissions.

To address these needs, a tool is needed to *understand* and *test*:

i. *Impacts of transportation investments on land-use (and vice-versa)*. A key motivation for TCRP Project H-12 was the need for more complete and sensitive tools means for analyzing the impact of new transit infrastructure on land-use, and vice-versa. These impacts (all related) include: the volume of induced ridership; development that would be attracted to stations; and, corridor- or even regional-level changes in modal share. (Similar impacts occur with new road infrastructure as well: induced traffic volumes; development attracted to major junctions; corridor- and regional-level modal share changes.)

   With regards to the *impact of land-use (urban form) on transit use*, Project H-12 identified seven key factors that influence travel activity: residential density; transit supply; auto ownership; socio-economic factors (e.g., income, age, gender, occupation, etc.); employment density; accessibility (i.e., how well connected a given location is with human activities such as work sites, etc.); and, neighborhood design.

   With regards to the *impact of transit on land-use*, Project H-12 found that:

   - Fixed, permanent transit systems have the greatest impact.
   - Transit's impacts are measurable only in the long-term.

- Transit's impacts on land / development **markets** -- not on land **values** -- must be considered.
- Transportation is a facilitator of development -- not a cause.

ii. *Impacts of urban (and other) policies on transportation and land-use*. The impact of alternate land-use scenarios (e.g., 'compact' urban form versus sprawl) on alternate transportation network configurations (e.g., transit-intensive versus auto-oriented) can be tested effectively only with integrated models.

iii. *Behavioral responses to price mechanisms*. An increasingly important aspect of land-use, travel demand and integrated models is the need to simulate how the 'actors' respond to changes in costs and prices. A topical example is road pricing (drivers' response to tolls). However, how people 'choose' where to live and work is described not only by 'physical' attributes such as vacant land, developed office space, etc., but also by economic (pricing) considerations: the cost of housing, the job market, the cost of transportation, and so on. Similarly, pricing mechanisms define the decision to acquire (or not) an automobile(s); the importance being that auto availability is a critical determinant of trip-making, mode share, etc. Moreover, the supply of home-end and work-end space also is determined in part by a pricing mechanism, to which developers and employers must be sensitive.

State-of-the-Future: The "Ideal" Urban Model

TCRP Project H-12 defined the framework for enhancing integrated models in terms of an 'ideal' model. It addressed three issues: required capabilities; a conceptual framework; and, an assessment of how existing operational integrated models fit the conceptual framework.

What Should Integrated Models Be Able To Do?

Integrated urban models should be:

- *Theoretically sound*, based on the determinants of the "transportation - land-use" connection.

- *Result-driven*, but respectful of due process and other practicalities (such as the input data that are, or are likely to be, available).

- *Responsive to the issues faced currently by MPOs, transit operators and others involved in urban transportation planning*, including finances, legislative requirements, local zoning, public accountability, the role of the private sector, etc.

- *Cognizant of the regional, state, national and global demographic and economic inter-relationships* that guide the pace of urban development.

- *Practical to operate*, with meaningful outputs and a traceable, defensible process.

- *Sufficiently flexible* to accommodate the varying scales and sizes of different cities.

- *Presentable* in an understandable way to decision-makers and the public.

The 'Ideal' Integrated Model: Concept

Figure 1 is a highly idealized representation of a comprehensive transportation - land-use modeling system. At its core (the shaded area of Figure 1) are four inter-related components:

i. *Land development*, which models the evolution of the built environment and the building stock.

ii. *Location choice*, which models the locational choices of households, firms and workers.

iii. *Activity / travel*, which simulates the trip-making behavior of the population.

iv. *Auto ownership:* this component models household auto ownership levels -- an important determinant of household travel behavior.

Points to note concerning these four "behavioral core" components include the following:

- *The components are related*. However, the model must distinguish clearly among the four components, since each involves very different actors, decision processes and time frames.

- *Each component involves a complex set of sub-models*. Market-based supply-demand relationships tend to dominate aggregate behavior in each case, with prices both determined endogenously and largely determining the outcome of these supply-demand interactions. Models that ignore these key interactions may not fully capture the dynamic evolution of the urban system over time.

- *The model must account for the inter-relationships over time*. For simplicity, Figure 1 depicts the short-term impacts in which, for example, such factors as location and auto ownership generally are fixed. However, over time, these factors clearly will evolve in response to changes throughout the system (for example, people relocate their homes and/or jobs at least partially in response to accessibility factors, etc.).

- *Auto ownership is an essential component to the process*, rather than as simply one more (often exogenously determined) input to the travel model. As Ben-Akiva [1974] has observed, however, auto ownership is an integral part of the "mobility bundle" in that it is fundamentally interconnected with residential location and work trip commuting decision-making.

Figure 1 illustrates four major *drivers* of urban systems, some of which may be treated as exogenous or endogenous to the model: *demographics* (the evolution of the resident population); *regional economics* (the evolution of the regional economy); *government policies* (zoning, taxation, interest rates, etc.); and, *the transportation system* (the road and transit networks, etc.).

In the ideal conceptual model, land development, location choice processes, and job-worker linkages are all modeled as economic markets with explicit supply and demand functions and procedures for price determination and "market clearing" (i.e., the allocation of supply to demand). The model would be dynamic, disaggregate and behaviorally sound and, therefore, sensitive to a wide range of land-use and transportation policies and able to trace the direct and indirect impacts of any of these policies through time and space. Details may be found in Miller et al. [forthcoming].

Inventory of Current Modeling Capabilities

Given current data availability, modeling techniques and theoretical understanding of behavioral processes, it is possible to develop and achieve the ideal integrated model, with a concerted research and development effort. To start, a selection of existing integrated models was reviewed, in order to prepare an inventory of the current state-of-the-art as a basis for further development.

Six currently-operational models were assessed. This assessment resulted in four conclusions:

i. All models are sensitive to transit - land-use interactions, but to varying extents.

ii. All currently operational models fall short of the ideal model to varying extents**.**

iii. At the same time, current models individually and collectively display many strengths and generally provide a solid basis for further evolutionary improvements.

iv. Despite recent advancements and the scope for significant evolutionary development among existing models, a "new generation" of integrated models must be developed in order to fully achieve the ideal model.

Development Taxonomy

How can the ideal future model be achieved? The four aforementioned conclusions led to recommendations for a two-part program: As noted above, the long-term R&D program is directed towards producing the ideal, 'next generation' integrated model. This would be based on a short-term *evolution* of existing capabilities and data, in order to maximize current potential, quickly and at minimal cost, while moving towards the ideal integrated model.

As a first step, Figure 2 classifies current and *future* land-use and transportation modeling capabilities. This classification recognizes that different cities are at different points along the evolutionary path. The classification is then used to identify development paths towards the achievement of the ultimate long-term product; i.e., the ideal, next generation integrated model. Six incremental levels (ending with the ideal model) are identified.

In Figure 2, rows correspond to different levels of land-use modeling capability. While a continuum of levels obviously exists, five significant land use modeling 'states' or capability levels have been explicitly identified in Figure 2:

L1. None: The planning agency does not in any way model or forecast land-use.

L2. Activity + judgement: Activity levels are estimated and systematically allocated to zones, on the basis of considerable professional judgement.

L3. Non-market-based land allocation model: A formal land-use model exists, but is not market-based (i.e., it does not include endogenous price signals or an explicit supply process). Some current models use this approach.

L4. Land allocation with price signals: A formal model is used, which includes endogenous price signals, but does not include a full demand-supply market process representation. This type of model does not currently exist. The potential role of such a model -- in light of the overall long-term goal -- is discussed further below.

L5. Fully integrated market-based model: A full system of market-based supply-demand relationships with explicit prices is used. Many current models use this modeling approach, as does the 'ideal' model.

Similarly, the columns in Figure 2 represent different levels of travel demand modeling capability, of which four are explicitly shown:

T1. No transit or mode split model: Only roads and auto travel are modeled.

T2. Transit with simplified (non-logit) mode split: Transit is represented in the modeling system, but modal split is performed using simplified (non-logit-based) methods. Assignments are usually based on daily (24 hour), rather than peak-period, volumes, usually using some form of capacity-restrained assignment. The modeling system is not usually iterated to achieve internal consistency.

T3. Logit mode split; peak-period assignment: A disaggregate logit or nested logit mode choice model is used. Peak-period equilibrium assignment is used. The system is iterated to achieve internal consistency. This level of travel demand modeling capability defines the current 'best practice' for medium to large cities.

T4. Activity-based methods: This is an emerging approach -- i.e., it goes beyond current best practice. The traditional four-stage process is replaced to varying degrees by activity-based (as opposed to trip-based) models. Portland, Oregon is the most advanced along this path of model development in the United States, by far, with a few other cities experimenting to varying degrees. The thrust of TMIP's "Track D" is to move U.S. modeling practice towards this 'next generation' travel demand modeling approach.

Each cell in the Figure 2 matrix represents a land-use - transportation modeling combination. Virtually all cities can be categorized as being currently contained within one of the 20 cells in this matrix. Points to note about this matrix include the following:

- There are six *desirable* incremental capability levels, shown by the arrowheads on Figure 2.

- "Appropriate" combinations of transportation and land-use modeling capabilities generally follow the major diagonal (i.e., from upper left to lower right). That is, it makes little sense to combine a very complex land-use model with a very crude travel demand model, or *vice versa* (although there are cities that currently have sophisticated travel demand models with little or no land-use modeling capability).

- The "appropriate" cell for a given city obviously depends on a number of factors, including the city size, the nature and extent of its transit system, the extent to which it is interested in pursuing land-use as a policy tool, etc.

The arrows in Figure 2 depict logical / recommended "development paths" or trajectories for urban areas desiring to upgrade their modeling capabilities. The arrow's base represents a current capability (e.g., L1,T1: no land-use model, no transit representation). The arrow's tip represents a logical incremental upgrade on that capability (e.g., L1,T3: no land-use model, 'best practice' travel demand model).

Although the L4 capability (land allocation with price signals) does not yet exist, Figure 2 shows the L4, T3 model combination as a short-term goal. This is a realistic objective for advancing the state-of-the-practice in integrated modeling in advance of the long-term realization of the ideal model, for two reasons:

- It reflects a travel demand model structure (logit / peak-period assignment) that is relatively well advanced which, therefore, can draw from a wide body of literature and practical installations. Therefore, it is readily achievable.

- This class of land-use model would be an improvement over non-market based land allocation models, but does not require a complete, fully integrated market-based model (L5). Thus, it represents an attractive short-term advancement towards the ideal long-term model.

Finally, Figure 2 shows 'first' and 'advanced' paths of development. The ordering of movement is important, since -- as noted above -- advancements in both types of models are linked and therefore must be coordinated. Two advanced paths are noted:

- Movement from minimal travel demand / no land-use modeling (L1, T1 or L1, T2) capabilities is recommended *first* towards improvements in travel demand modeling (T3), *then* in land-use modeling (i.e., horizontally then vertically). But it also is practical to augment this time with a corresponding improvement towards minimal land-use modeling capability (L2).

- More important is the sequence of movements from the short-term goal (L4, T3) to the long-term goal (L5, T4). Here, the recommendation is to advance *first* towards fully integrated market-based land-use model (L5), *then* towards an activity-based travel demand model (T4). This sequence reflects the more advanced operational status of market-based land-use models, compared with activity-based travel demand models. However, an acceptable alternate treatment is the reverse order: T4, then L5.

Improving the State-of-the-Practice

General Guidelines

The advancement along the development paths also takes into account earlier recommendations; notably, those of the 1995 TMIP Dallas conference on land-use models. Specifically, the conference made seven recommendations for improving existing models. Each of these recommendations applies generally to the achievement of the six incremental capability levels, as follows (adapted from Shunk et al. [1995]):

i. *GIS links are required*. The availability of geographic information systems in a planning agency generally must be considered as a given. Many of today's commercially available travel demand forecasting models have links with some of the more widely used GIS packages; there exists at least one commercial model built into a GIS. However, with that one exception, many of the linkages are unidirectional, in which model networks are derived from GIS network definitions (but the GIS cannot easily import the model networks). Customized integrations exist, in which various components of model networks, matrices and processes can be exchanged with a GIS. At least one existing integrated model has a GIS interface.

   A full GIS interface would permit the bi-directional exchanges of data, and would support the exchange of matrices and processes as well as model networks.

   The large number of GIS packages in use among planning agencies means that a single standard for data exchange does not yet exist. As well, many GISs have been established primarily for design, operational and maintenance purposes (whose data requirements can differ from those of planning needs -- for example: connectivity is an essential requirement for a transportation model network, but is not necessarily needed for design purposes. Also important is the need for disaggregated data inputs.). Therefore, it is essential that modeling / planning requirements be incorporated early on in the development of a GIS (and that modeling initiatives take account of GIS).

ii. *Comparative descriptions and evaluations of existing models are required*. The lack of a common overall algorithm, the many initiatives taking place around the world and the different levels of land-use modeling capabilities means that a comparison of existing modeling capabilities can be difficult. Several attempts have been made in recent years; including an 'inventory' of current capabilities in Hunt et al. [forthcoming]. Other comparisons include Wegener [1995] and Southworth [1995]. These comparisons describe the technical capabilities of existing models, from which their applicability to a particular situation can be determined. They also provide useful sources of evaluation criteria.

iii. *Time-series validation of models are required*. The development program of any of the six incremental modeling capabilities should include model validation; either through 'backcasting' or by building in an ability to monitor forecast results over time.

iv. *The availability and quality of employment data must be improved*. The 1995 Dallas conference considered this to be the single highest priority item. As movement progresses towards the inclusion of pricing mechanisms and signals in the land-use models, it also will be necessary to include and analyze 'space prices' (development, rents, etc.).

v. *Better means of assessing model outputs are required*. More rigorous and systematic methods for judging reasonableness of model results are required. These must be based upon mathematical and statistical goodness-of-fit measures, but also must include 'reasonableness' checks. These must be included in the specification of any model development program.

vi. *Sketch planning methods for evaluating land-use - transportation impacts are required*. These likely represent a different level of complexity from the modeling initiatives discussed above. However, one implication is that any model development program should explicitly consider how the results are to be presented and tabulated, and how the results can be interpreted and documented for future use in sketch planning.

vii. *Improved feedback is required* among existing land-use, transportation and environmental models. Inherently, each of the six incremental capability levels aims to implement and improve feedback. Any model development program must explicitly test and control for different 'scenarios,' in order to be able to isolate, monitor and analyze the feedback impacts (for example: the expected different impacts on transportation of compact *versus* sprawl land-use distributions, etc.)

Research and Development Program

The proposed long-run R&D program contains five closely related components:

i. Training of professional staff and dissemination of technical information;

ii. Data collection, assembly, documentation and dissemination;

iii. Implementation and evolutionary development of existing models;

iv. Development of the "next generation" of urban models; and

v. "Non-model-based" (complementary) research and analysis designed to improve both our understanding of land-use - transportation interactions and our ability to analyze urban policies.

The fourth and fifth components generally represent long-run R&D activities. The third component (development of existing models) both improves the state-of-the-practice and provides a bridge to the two long-run R&D activities. Components i and ii (training and data) support and are interconnected with all other tasks -- for example, "information flow" among the other three components would be maintained by the over-arching information and data dissemination components.

Thus, the first three components (i, ii and iii) all have aspects that are applicable to the short-run improvement of the state-of-the-practice. The main features of each component are described in the sub-sections below.

As proposed in Project H-12, important aspects of the R&D program were the dual needs for sustained funding and nation-wide coordination. These needs are inherent to the discussion that follows.

Implementation and Evolutionary Development of Existing Models (Component iii)

Building upon earlier initiatives (notably; the 1998 TMIP land-use modeling conference), a '*case study*' approach is proposed. This a short-run action that both improves the current state-of-the-practice and provides crucial input to the development of the long-run ideal model.

The case study approach brings together academics / researchers and MPOs or other agencies, with the aim of introducing or upgrading existing modeling capabilities at the agency -- i.e., moving the agency along the development path described in Figure 2. The result is a practical model, tested in actual operating conditions that are particular to the agency. Project H-12 proposed a coordinated series of case studies, in order to test different conditions (e.g., size of the city, extent of rapid transit, high / low growth, etc.) and model combinations (i.e., locations on the development path).

The technical coordination and specification of the case studies could be done through a peer review panel, which would review technical specifications; develop 'goodness-of-fit' criteria; ensure technical consistency; help in the technical evaluation of proposals; and, provide technical advisory services.

The case study approach is designed to address two common barriers to the more widespread use of integrated models: the lack of in-house resources (i.e., insufficient expertise and money to implement a model), and the lack of well documented 'success stories' which can encourage agencies to proceed with the modeling effort and can provide practical references.

Benefits of the proposed case study program include:

- Direct improvements to the state-of-the-practice in many locations.
- Operational experience that can be extrapolated elsewhere.
- Cost-effective means for controlled experimentation.
- Practical, direct way to improve databases for both operations and research.
- Trained staff.

Training and Information Dissemination (Component i)

A major barrier to the implementation of integrated urban models is a lack of trained staff in MPOs who can properly use these complex models. Here, "trained" not only means experience with the mechanics of running a given software. Much more important, the term also means having a sufficient technical understanding of the behavioral and methodological foundations of the modeling system, so that staff can apply appropriate judgement in operating the model and interpreting its results. Such training can be supported by a number of actions, including:

- *Short training courses and seminars*. These could address both theory and practice (e.g., an overview of current and emerging integrated urban modeling practice, the application of integrated models to practical situations, etc.).

- *Development of "best practices" manuals, case study reports and other aids* for self-learning and reference.

- *Development of a manual on sketch planning methods* for integrated land-use - transportation analysis; perhaps along the approach of a 'quick-response' system.

- *Literature reviews* on selected topics not dealt with elsewhere.

- *Dissemination of the documented results* of the implementation case studies and, eventually, the R&D efforts that would result from components iv and v.

- *"Integrated modelers' users group"* for the exchange of information, problem solutions, etc.

- *Promotion of 'special interest groups'* among parallel/related professional organizations, such as the American Planning Association, etc.

Project H-12 also proposed the development and maintenance of a well-advertised web site. The web site would provide planners with access to a centralized library of information concerning integrated urban modeling. It also would also provide a central contact point for the proposed users group. Information contained within the web site could include:

- All reports and other documentation generated by the aforementioned activities.

- All manuals and other training materials.

- Documentation of existing models.

- Literature reviews, annotated bibliographies, etc.

Database Assembly and Management (Component ii)

Data limitations may well be the most frequently cited obstacles to the development of operational integrated urban models, as well as to research efforts in this area. The importance of an improved national database for land-use - transportation analysis and modeling cannot be underestimated, both for modeling and for policy- and plan-making in general. The improved database can be achieved through three key activities:

i. *Development of a centralized data library*. The library would contain well-documented databases from a number of urban areas, compiled from the case studies as well as existing sources. A condition of funding support would be the provision of documented databases to the centralized data library, to be available to any planner or researcher who wishes to access them. The data library is critical in supporting the evolution of integrated urban modeling, since it promotes:

   - Cross-city comparisons of transportation - land-use interactions.

   - Tests of model transferability, in which a given model is applied to multiple locations.

   - Cross-testing of multiple models within one or more urban areas.

   - The development of national default parameters and relationships.

   While the exact contents of these databases will inevitably vary from one urban area to another, it should prove possible to impose minimum standards upon their contents and structure to facilitate the sorts of comparative analyses described above.

C *Development of data collection standards and procedures*, especially with respect to critical data items that currently are often not well handled in many urban areas. This might include developing recommended procedures for using tax assessment and/or real estate databases to support modeling activities; procedures for collecting and maintaining employment databases; and, possibly, procedures for collecting goods movement data.

C *Assistance for <u>selected</u> data collection efforts*. While generalized, nation-wide support for data collection is probably beyond the budget of even the most extensively funded program, very focussed funding of special, high-return data collection efforts should prove to be very cost effective. One example is the development of a very high quality micro-level database for portions of one or more cities to support R&D efforts with respect to micro-scale modeling [Deakin and Lathrop, forthcoming]. Another example is support for pilot-testing of novel data collection methods, particularly if they address one of the traditionally problematic data items (employment, price data, firm location choice, etc.).

Summary

This paper has provided an overview of ways to improve the state-of-the-practice in integrated urban modeling capabilities. The overview is drawn from a recent TCRP project, which developed the specifications for the ‘ideal,’ next generation of integrated urban models. The TCRP project developed a two-part development program for developing the ideal model: a long-run R&D program, and a short-run list of improvements. The short-run improvement program is intended both to provide a basis for the long-run R&D effort, and to upgrade existing capabilities. Other potential benefits include improved data bases, the development of staff resources and capabilities within MPOs and other planning agencies, and the development of a nation-wide knowledge-base of expertise in integrated urban modeling.

The importance of, and current interest in, integrated urban models lies partly in the need to meet legal and technical requirements in urban land-use - transportation planning. At the same time, however, there is a need to be able to test and understand the implications of land-use and transportation policies and plans on each other.

Disclaimer

The opinions expressed in this paper are those of the authors only. Responsibility for the veracity of the contents of this paper lies with the authors alone.

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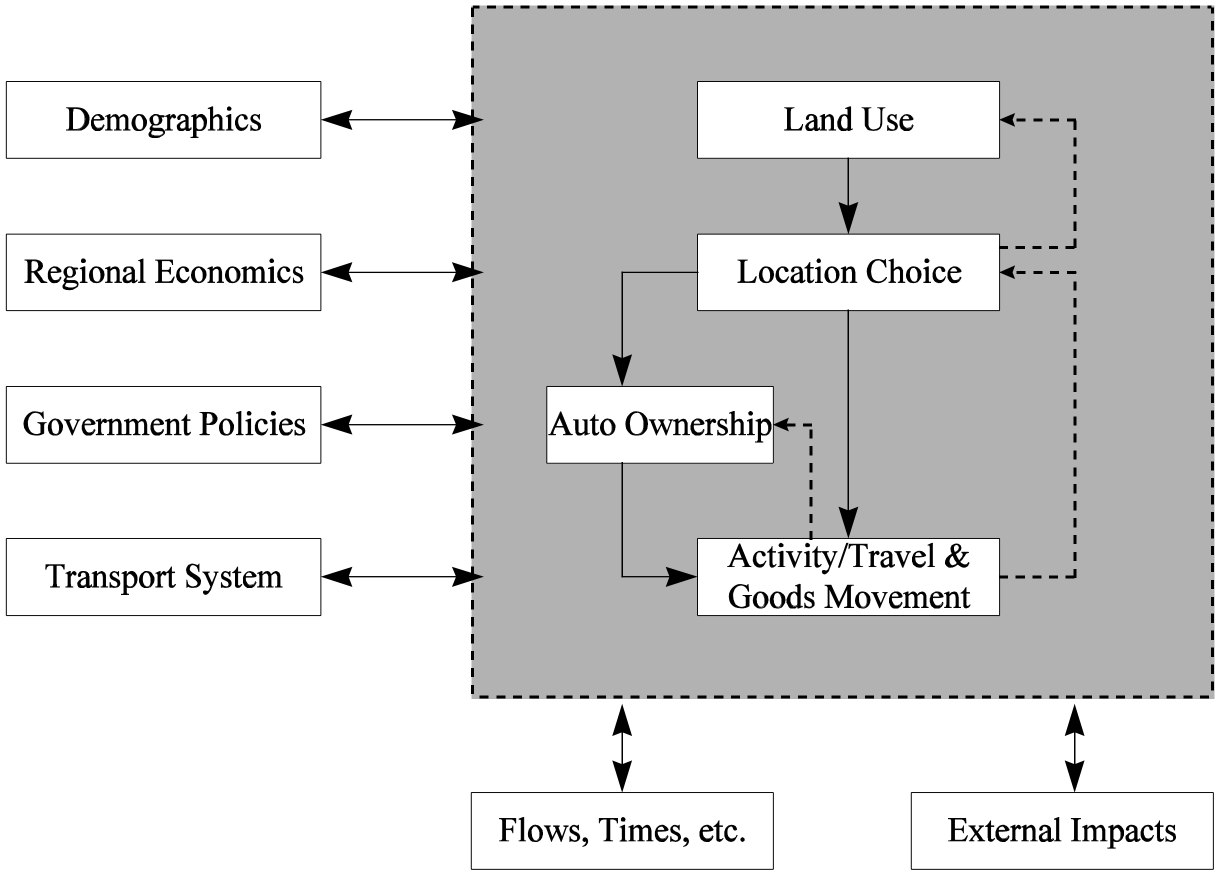

Figure 1
Idealized Integrated Urban Modelling System

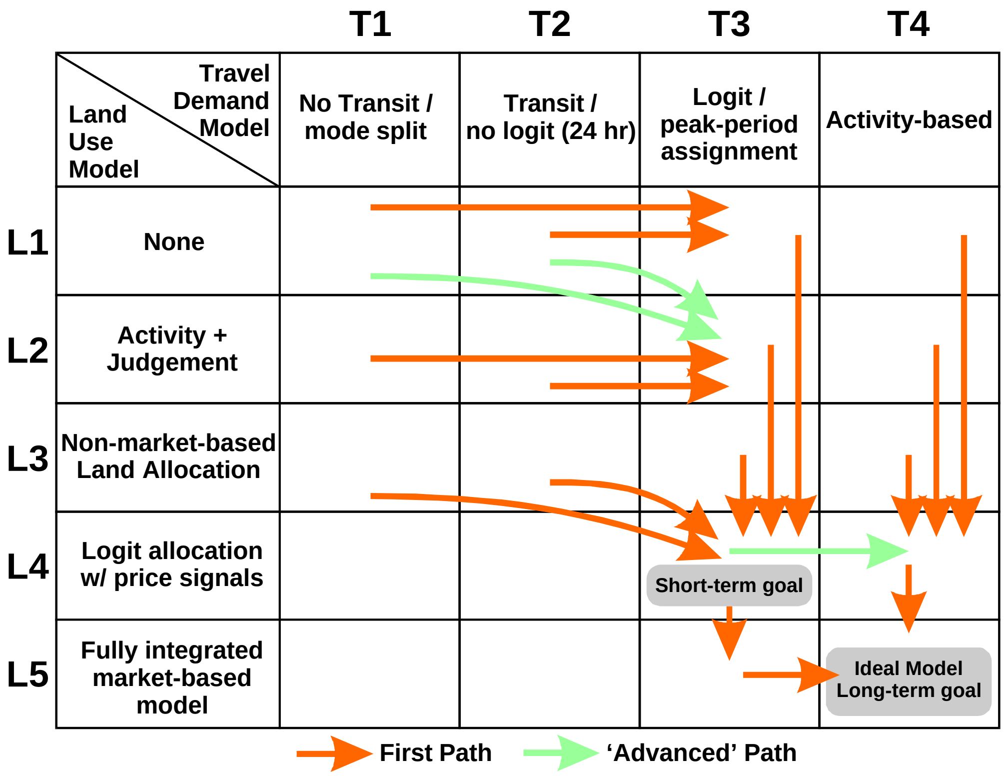

Figure 2. A Taxonomy of Land-Use / Transportation Modeling Capabilities

Transit as Environmental Mitigation

Hasty Evans, *Massachusetts Bay Transportation Authority*

Abstract

The depression of the Central Artery through the heart of downtown Boston and the building of the Third Harbor Tunnel (the Ted Williams Tunnel) gave rise to the concern that this addition to the highway system would simply add to the traffic congestion and downgrade the quality of the air in the central city. The planning for the CA/T project (as it is called) was done before the Clean Air Act was passed. Consequently, a series of agreements was reached by which the environmental groups would ensure air quality during and after the construction project. Many of these agreements involve changes to the mass transportation system in and around Boston and many of the projects fall under the aegis of the MBTA. Finally the system set up an oversight committee to ensure compliance with the agreements.

The presentation will detail the specific transit related commitments required under the construction agreement for the central artery, and the process by which these commitments were determined. For specific MBTA commitments, the presentation will detail each obligation. This will include background on the need identified by the proponents and the benefits that the project is expected to provide. Special emphasis will be given to looking at the innovative ways the MBTA has used to meet the requirements associated with each project. The work will encompass results of the completed projects and projections for impacts from the projects that are under construction and still in the planning stages.

Some time will be given to a discussion of the Environmental Oversight Committee. This is the compliance oversight committee set up in the process. The presentation will look at the necessity for this oversight and its role in the public process.

Finally, any discussion of mitigation must talk about cost. We will examine the cost to date of the compliance, and discuss the final estimated cost of all the obligations. Time permitting we will breakdown the cost into cost per air quality benefit.

Pace Customer Satisfaction Index Program: The Voice of the Customer

Carol Guziak, *Pace Suburban Bus Service*

Abstract

In 1996, Pace Suburban Bus Service, a suburban public transportation agency headquartered in Arlington Heights, Illinois, embarked on a new movement to integrate customers perceptions of the service offered into its daily operations. The company focused on increasing ridership. Along with developing a Vision/Mission statement, a tool was developed to continuously monitor and evaluate the services offered from the customers point of view that is called Customer Satisfaction Index (CSI). Initially, Pace focused on Fixed Route Service; that is, it's regular, express, subscription and municipal services. Pace plans to develop a customer satisfaction program for it's Vanpool and Paratransit services in the coming years.

Customer and employee focus groups were conducted. These sessions helped to determine the service elements that were important to customers. Customers and employees completed an importance survey that rated the importance of the service elements. Responses to this survey formed the basis of the satisfaction survey. A pretest of the satisfaction survey was conducted at the end of 1996 at one of the major divisions to determine its validity.

Full implementation of the CSI began in January 1997. As a continuous program, a one-page satisfaction survey, printed in English/Spanish/Polish, is distributed on-board fixed route buses, regular and express, on a random sample basis throughout a four-month period. For the regular and express fixed route services, Pace chose to sample 120 one-way trips at each of eleven reporting units (nine divisions, contract carriers operating all day trips and contract carriers operating peak period trips) per period. All subscription and municipal bus riders are surveyed once per year. Market Research presents the results to the management, the Pace Board of Directors and the Pace Citizens Advisory Board. The results are communicated to customers via bus car-cards and in the Pace Rider Report (a quarterly customer newsletter) and to employees by E-mail, through office posters and in the employee newsletter. This process repeats itself every four months.

Introduction

The Customer Satisfaction Index (CSI) was developed and implemented because of Pace's need to better understand its customers and their perception of service offered. Initially Pace focused on Fixed Route Service; that is, its regular, express, subscription and municipal services. Pace plans to develop a customer satisfaction for its Vanpool and Paratransit services by the end of the year 2000.

In 1996, the company embarked on a new movement to integrate customer's perception of the service offered into its daily operations. Focusing on increasing ridership, the company's vision is to carry 42 million riders annually by the year 2000 and maintain a 36% recovery ratio.

While the suburban population and employment continues to grow, Pace ridership has remained relatively stable with ridership increasing almost 4% between 1997 and 1998 to over 39 million. The automobile continues to be the suburban bus service's biggest competitor.

In order for Pace to become a customer based organization, it needed to identify customers perceptions of service, determine what is most important to customers, measure customer perceptions and act on improvement opportunities. Therefore, a tracking mechanism was put in place that would establish performance targets, benchmark data collected, determine current levels of performance, trend data overtime and provide customer and employee feedback. This tracking mechanism is the Customer Satisfaction Index (CSI).

A Method to Measure Pace Fixed Route Service

The Customer Satisfaction Index (CSI) is the tool Pace chose for both managers and employees to continuously monitor and evaluate customers perceptions of the service offered. In developing the CSI, Pace's Market Research section investigated and determined what program best suited the company's needs. The concept was presented to upper management. A sponsor and champions were secured. Funds were obtained and committees and teams were established.

Stage of Development

Employees at every level were involved. Committees were created to determine the form and substance of the measuring tool. Once the statistical methodology and technical aspects were determined, Pace Market Research together with a consulting firm, outlined the steps that would aid in a better understanding of customers needs and expectation of service and satisfaction with the service offered.

Laying the Groundwork

The first step in the process was to lay the groundwork for developing a sound tool to measure customer perception of service. Goals and objectives were agreed upon. Employees and management were asked to identify the following:

- The Customer -Know who your customers are
- The Services - What products and services does your company offer its customers
- The Moments of Truth - areas where customers encounter and perceive service

Building the Index

The second step was systematically build a measurement tool that would assist the company in achieving its goals. The results of identifying types of customers, services and moments of truth were used as the basis of identifying and clarifying measures.

- Six focus group sessions were held, 3 for customers and 3 for employees, to define service quality, determine influencing factors and service expectations. An exhaustive list of service characteristics important to customers was developed at each session.

- An Importance Survey was developed and distributed to customers and employees to refine the service elements gleaned from the focus group session and determine elements considered critical to continued use of service.
  - 58 service elements measured
  - Results analyzed using exploratory factor analysis, general analysis of results and confirmatory reliability analyses

	Customers	Employees
Responses	11,700	448
Response Rate	28%	31%
Survey	On -board	Company-wide
Date	May 1996 (2 days)	June 1996
Distribution	70 Employee Volunteers	Departmental

  - A Satisfaction Survey was developed from the results of the Importance Survey.

- A pre-test was conducted to determine the validity of the Satisfaction Survey.
  - Test the use of a temporary employment agency for survey distribution
  - Test random sample trip method
  - 34 service elements pre-tested
  - Determine cost of non-employee surveyors

Pre-test Program Outline	Pre-test Key Findings
Hire Temporary Agency	Ineffective - generated 60% productive work time
Draw Random Sample	100 Round Trip Random Trips
Hire Surveyors	Inefficient work force - only 66.3% trip completion
Train Surveyors	Completed questionnaires were 340 shy of goal
Data Collection	Sampling by round trip was very difficult
Evaluate Effectiveness of Method	Cost was $3.76 per completed survey

- Service elements were finalized and grouped into six main categories based on functional activities; Operations, Maintenance, Fares/Transfers/Pricing, Routing & Scheduling, Waiting Area & Boarding and Information.

- Final buy-in from key committees had to be gained for the following:
  - Survey method
  - Sampling size
  - Distribution Procedures

- With management input, weights were assigned to the main categories based on mean score rating from the Importance Survey.

Main Group	Weight
Operations	20%
Maintenance	15%
Routing & Scheduling	15%
Fares/Transfers/Pricing	15%
Waiting Area & Boarding	20%
Information	15%

- Management established a long-term company target of 4.0 mean for all main groups.

- A final Satisfaction Survey was developed and approved by management. It consists of the following:

10 Marketing Questions	31 Satisfaction Questions
History of Riding	Operations
Frequency of Riding	Maintenance
Route Rode	Routing and Scheduling
Identification of Other Vehicles Used	Fares/Transfers/Pricing
Trip Purpose	Waiting Area and Boarding
Market Segment	Conditions
Customer Loyalty	Information

- The Index was developed by establishing a baseline score. The first reporting period is considered the base period and a benchmark for determining the index values in subsequent periods. The base line index value is set to 100 points with each period scores evaluated above or below the base period.

- Mean scores were used to present customer satisfaction results. Customers rate 31 service elements on a 5 point scale with 1 being "very dissatisfied" and 5 being "very satisfied". The service elements mean scores were rolled into a particular grouping based on functional activity. Individual service elements and main groups were tracked over all completed periods.

- Riding characteristics and degrees of loyalty were presented as percentages with results shown for the period being reported.

Problem Solving Loop

The Problem Solving Loop assess periodic performance, reviews results and determines the need for and implements improvement strategies.

- In assessing periodic performance, the Procedures Committees, created 11 reporting units composed of 9 divisions and 2 contract carrier services. Surveys would be distributed and collected would be weekly at the divisions and monthly for the contract carriers.

- The survey consists of the following:
  - One page questionnaire with marketing and satisfaction rating questions
  - Marketing and satisfaction questions
  - Two formats
  - English/Spanish
  - English/Polish
  - A monthly pass incentive is offered to customers if they complete the customer information section
  - Customers are also asked if they would like to participate in possible future Pace research
  - A CSI customer hotline number is printed at the bottom of the questionnaire (847) 228-3581 for comments on the survey or service.

- Sampling is done in the following manner:
  - Continuous random sample
  - One-way trip
  - 120 trips at each Reporting Unit (9 Divisions, All Day & Peak Contract Carriers)
  - 20 questionnaires per trip
  - Significance testing is done in banner cross-tabulations
  - System satisfaction scores are derived by applying a weighting to all responses in proportion to the number of actual one-way trips (changing to actual ridership) operated by each reporting unit

- The report is formatted and distributed to management every four months. The format consists of an overview, survey results with index values and satisfaction ratings for the service elements, marketing information and implementation progress report of each reporting unit. The reports are packaged in the following manner:
  - System & All Reporting Units report for upper management
  - System & Regional reports for regional management
  - System & Division reports for divisional management
  - System report for all other managers, the Pace Board of Directors, Citizens Advisory Board

- The process repeats itself every four months. Periodically there is an evaluation of the process and enhancements are made as needed.

CSI Results

The following results were reported to management for the first five periods (January 1997 through August 1998):

- 1997 Satisfaction Full Year Statistics (3 periods combined)
  - 3,950 trips randomly surveyed
  - 2,983 trips completed
  - 75.5% completion rate
  - 110,120 questionnaires boarded
  - 23,576 questionnaires completed
  - 21.4% reception rate

- 1998 Satisfaction Statistics – January through August (2 periods combined)
  - 2,640 trips randomly surveyed
  - 1,735 trips completed
  - 65.7% completion rate
  - 63,140 questionnaires boarded
  - 12,016 questionnaires completed
  - 19.0% reception rate
  - 92% completed in English, 7% in Spanish, 1% in Polish

- System Index

	Mean	Value	Score
Period 1- 1997.1	3.96	79.20	100.0
Period 2 - 1997.2	3.95	79.00	99.75
Period 3 - 1997.3	3.94	78.80	99.49
Period 4 - 1998.1	3.96	79.20	100.0
Period 5 - 1998.2	3.94	78.80	99.49

- Customer Loyalty Results
  - Customer Loyalty is measured by three factors:
    - Overall Customer Satisfaction -- "Overall satisfaction rating (1-5 scale)"
    - Likelihood of Continuing -- "Do you plan on riding Pace a year from now?"
    - Likelihood of Recommending -- "Would you recommend Pace service to others?
  - Customer Degrees of Loyalty Results

	Secure	Vulnerable	Potentially Vulnerable	Highly Vulnerable
Period 1997.1	32%	38%	20%	10%
Period 1997.2	30%	40%	20%	10%
Period 1997.3	29%	40%	20%	11%
Period 1998.1	30%	40%	21%	9%
Period 1998.2	31%	39%	20%	9%

- Customer Riding Characteristics (1998.2 Riding Tenure)
  - 7% - Less than 1 Month
  - 18% - 1 Month to 1 Year
  - 29% - 1 to 5 Years
  - 46% - 5+ Years

- 1998.2 Riding Frequency
    - 9% - 0 to 1 Day
    - 5% - 2 Days
    - 9% - 3 Days
    - 8% - 4 Days
    - 45% - 5 Days
    - 24% - 6 to 7 Days

- 1998.2 Vehicle Usage During Pace Trip
    - 31% - CTA Train
    - 28% - CTA Bus
    - 17% - Metra Train
    - 23% - Another Pace Bus
    - 34% - Only Pace

    (Multiple answers allowed)

- Trip Purpose
    - 71% - Work
    - 12% - Shop / Restaurant
    - 11% - Personal Business
    - 8% - School

Improvement Opportunities

To determine the need for improvement & implement improvement strategies, management at the Corporate office and at all Reporting Units review the CSI results and determine ways to improve those service elements below the targeted goal level.

Quality teams at the Divisions are working on projects in the following areas:

- Comfort level on buses: Future bus orders will have a specific control that the drivers can use to adjust the air conditioning in the buses by four degrees up or down. This new device will give them some flexibility with the bus temperature.

- Condition of Shelters: The North Shore Division is working with Pace's Sign and Shelter group on the conditions of shelters in their service area.

- Identification of Stops: The North Division is looking at the CSI results to improve sign locations at the Navy Base and Gurnee Mills. Schedule route operating times were added to bus stop signs for Route 567.

- Driver obeys and enforces rules: The Southwest Division is providing additional supervision on routes that are having problems. Depending on the nature of the complaint, supervision is sent out to discuss the details of the complaint with the passenger to ensure complete customer satisfaction is maintained in the resolution of each conflict.

- Buses running on time: The South Division reviewed congestion in the Southern suburbs, vehicle accidents or breakdowns. They are looking at recalculating running times on some routes, planning detours for standing trains and providing additional communication and interaction with the Maintenance section to keep buses running on time.

- Frequency of service and service when and where desired: The Northwest Division is reviewing CSI data by route to determine where frequency can be improved and additional service provided.

Subscription Bus Service

Pace offers Subscription Bus service, which is a premium bus service custom, designed for a group of 30 or more riders. The bus travels non-stop to an employment center after picking up riders at a few stops.

- Sampling
  - Evaluated on an annual basis in November
  - Customers riding subscription service generally remain constant
  - On-board survey conducted during the morning trips
  - Customers rate satisfaction service elements on a scale of 1 to 5 where 1 is “very dissatisfied” and 5 is “very satisfied”

- Report Format
  - Questionnaire
    - Modeled after the regular and express fixed route questionnaire
    - Some marketing and satisfaction questions are modified to reflect service
  - Index Value: Same method as for regular and express service
  - Service Elements
    - Same six main groups as for regular and express service
    - 4 service elements eliminated not applicable to Subscription Bus service
    - 2 service elements modified to fit Subscription Bus service
    - Mean scores calculated the same for regular and express service
  - Customer Loyalty: Calculated the same as for regular and express service

Municipal Bus Service

Pace offers Municipal Bus service, which is a free bus service, for residents of the Village of Niles and the Village of Melrose Park under contract by Pace.

- Sampling
  - Evaluated on an annual basis in November
  - Customers riding municipal service are generally the same each day
  - On-board survey conducted during the morning trips
  - Customers rate satisfaction service elements on a scale of 1 to 5 where 1 is “very dissatisfied” and 5 is “very satisfied”

- Report Format
  - Questionnaire
    - Modeled after the regular and express fixed route questionnaire
    - All the service elements in the "Fares/Transfers/Pricing" group were eliminated because the services are free
    - All other marketing and satisfaction questions are the same as for the regular and express service
  - Index Value: Same method as for regular and express service
  - Service Elements
    - Same six main groups as for regular and express service
    - 4 service elements eliminated not applicable to Subscription Bus service
    - 2 service elements modified to fit Subscription Bus service
    - Mean scores calculated the same for regular and express service
  - Customer Loyalty: Calculated the same as for regular and express service

Conclusion

In the final analysis, implementing the Customer Satisfaction Index benefits the company by aiding in achieving the Vision Statement, providing useful measures of customer's perceptions and meaningful changes which positively impact ridership. It communicates results to customers and employees and promotes teamwork at all levels. Used as a tool to improve, not criticize, teams can share improvements attained in one area in other places and be accountable for performance below the baseline and take action. The company, in turn, will recognize good performance and improvements and assess the effects of change.

Determining Intermodal Movements at Multimodal Transfers Facilities

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Abstract

Optimizing pedestrian and vehicular circulation at intermodal passenger terminals is sometimes hampered by the lack of sufficiently accurate information regarding the movement of passengers within the environs of the intermodal terminal. Transit operators can normally provide the data about the volume of vehicle boardings and alightings, but hard data about the volume of passengers moving between vehicles is often lacking. This concern is exacerbated in larger passenger terminals with retail and other ancillary activities, where transferring passengers seldom move directly between their vehicle of access and egress.

This was the case with Frankford Terminal, a multimodal passenger terminal operated by the Southeastern Pennsylvania Transportation Authority (SEPTA) in Northeast Philadelphia where about 15,000 weekday passengers transfer between elevated rapid transit train service, 15 surface bus routes and automobiles in a complex facility dating back to 1922. In its 75 years of operation, there never was (nor really needed) a clear accounting of the volume of passengers transferring between individual routes and services. The physical layout of the physical facility rendered direct observation impossible and other traditional survey and sampling techniques yielded inconclusive results.

The impending reconstruction of Frankford Terminal, however, represented an opportunity to rationalize the facility if sufficient data was available to support an operational analysis to optimize bus flows and pedestrian movements. A special survey was conducted to determine to a high degree of accuracy the number of passengers transferring between each set of bus and rail services on a typical weekday in quarter-hour increments. An innovative combination of high-tech and low-tech techniques we developed to collect and process data regarding passenger transfer movements during the course of a 39-hour continuous survey at Frankford Terminal. Data was gathered regarding almost 100 percent of the off-peak transfer movements and over 85 percent of the peak period transfer movements, providing an extremely high degree of accuracy to the profile of passenger transfer movements assembled to guide the design of the new facility.

This paper describes the design challenges posed by the existing terminal facility and the methods undertaken by the project team to overcome them. It details the logistics and methodology employed to successfully manage the development and execution of the passenger transfer survey, the innovative means developed to reduce data into a meaningful form, the conclusions derived from the survey effort and how examples of how the enhanced level of survey data accuracy positively influenced the final design of the new terminal facility. Finally, it concludes with general guidelines drawn from the case study that will assist planners in evaluating the relative effectiveness of alternative multimodal passenger facility designs.

Using GIS to Assess Demographic and Land Use Characteristics on Local Transit Services

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Abstract

In recent years, while a great amount of attention has been directed to the creation of metropolitan regional transportation systems, relatively little research and analysis has been directed to neighborhood and local community circulation services and local transit feeder services. This paper presents an analysis of community level and neighborhood transportation system using Geographic Information System (GIS). The paper assesses various demographic and land use characteristics contributing to the usage of neighborhood and local transit services and it addresses pertinent matters related to better understanding the need for and the successful implementation of community-based, local transportation services.

This paper presents studies of thirty community level fixed transit routes. Using the origin-destination information and detailed land-use maps obtained from the city of Los Angeles, a Geographic Information System (GIS) data base was developed including service routes; land use patterns; traffic volumes and census of population and socioeconomic characteristics. A statistical analysis was performed to derive any relationships or patterns between the existing community transit routes and land use and socioeconomic variables.

The results revealed that the community level bus routes (fixed transit routes) caters largely to business activities and primarily serves an employed population for non-commuting trips. A cartographic assessment of the routes showed that high loading patterns are associated with commercial and service areas.

Introduction

The Los Angeles County area has an unusually high concentration of community–level transit services. Among these are 23 public transit systems, which are fixed-route, community oriented services. Typically these systems are operated by cities and consist of buses less than 40 feet long. They charge low rates between 25 and 50 cents, and provide circulatory or shuttle services within the limits of the city that operates the system. These systems are almost invariably funded by a half-cent sales tax passed by Los Angeles County residents in 1980 in a measure known as Proposition A. Since Proposition A funds are dedicated to transit, many cities created small circulation bus systems to utilize the available funds. The cities therefore tend to be less concerned about farebox returns, instead focusing on providing service to as many of their residents as possible.

The unique nature of funding and the focus of various community-level transit services provide researchers with a unique opportunity to analyze the pattern of usage and also to understand trip generation and attraction characteristics in various neighborhoods. While a number of these services are fixed-route, their small-scale nature allows us to analyze the importance of various demographic variables and land use characteristics for explaining the pattern of trip loading and unloading. Geographic Information Systems (GIS) are by far the best tool for this type of research. Among the various applications that could be performed through GIS is in the area of trip generation rates. While various documentation provide this information by land use, they usually lack accuracy and/or adequacy for understanding community-based transit needs. This paper attempts to fill this gap by analyzing the trip characteristics of a local community transit provider in Los Angeles County.

Methodology

Assessing community-level transit service requires both an in-depth knowledge of the area to be studied and micro-level trip generation data. Changes in the demographic makeup of a neighborhood and its surrounding land use can greatly affect the geography and pattern of usage. In order to avoid the analytical problems associated with demand-based services (e.g., complex networks with little repetition of routes), this study chose to utilize the information provided by DASH (Downtown Area Short Hop) service. This is a fixed-route community-level transit in the County of Los Angeles and is operated by seven independent contractors. To avoid the problem of weekly variations in the level and pattern of usage, data for the entire period of April through June of 1996 was used for the analyses presented in this paper.

This study focused on thirty routes provided by DASH service. The origin-destination data and detailed land-use maps were obtained from the City of Los Angeles and were assembled for analysis. Using the origin-destination information, a Geographic Information System (GIS) database was developed including service routes; land use patterns; traffic volumes; and census of population and socioeconomic characteristics. The following illustrates the step-by-step process for building the community-level geographic system and the statistical analyses utilized to understand the pattern of usage.

GIS Database Development

DASH provided data on 17 bus routes in Los Angeles County (i.e. the location of each station, the number of passengers who got on and off the bus at each station and the load value for each connecting link in the network). In order to measure the impact of different variables on the patterns of usage, this data had to be digitally transformed into a Geographic Information Systems (GIS) environment, so that various site characteristics could be attached to each station and its connecting links.

<u>Creating Digital Bus Routes</u>

Of the data regarding 17 bus routes, 13 were made up of two distinct directional networks (i.e. clockwise and counter-clockwise). The 13 bi-directional routes resulted in 26 digital layers (i.e., files). With the addition of four files for each single direction route, 30 distinct databases were created. In order to conduct micro-level analysis, a unique ID was given to each of the bus stops on all routes. These stations were then assigned the passenger loading and unloading information. The ID code included a reference to the name of the route and its direction, if any. The final database contained loading patterns (i.e., AM peak, midday, and PM peak), and the total number of loading and unloading. For some stations, weekend data was also made available, and in those cases a separate analysis was performed.

An Arc View point layer file was created for each of the 30 files, which contained all the bus stops in a route. The bus stops for the routes were identified using the 1994 edition of the Thomas Brothers' Los Angeles/Orange Counties Street Guide and Directory and the 1995 US Census TIGER file for Los Angeles County. The procedure involved visually searching for the stop in the Thomas Guide and locating the same point in the TIGER file. Bus stops located at a street intersection were assigned the latitude and longitude of the intersection. For bus stops in which a feature, such as the name of a building (e.g. Kaiser Hospital) was given as a reference, the stop was placed at the middle of the segment of the street that ran alongside the given feature. Once located, each station received its pre-assigned ID (from the original database discussed earlier). The final point layer, consisting of all stations, was joined with the passenger database using the common ID.

The 1990 US Census information at the block level was then joined to the point layer using Arc View. This involved using a block group map of Los Angeles with the following list of variables attached:

- total population
- age
- race
- total number of employed
- industry of employment
- occupation
- educational attainment
- per capita income
- median household incomes

A GIS point-in-polygon procedure was used to attach polygon-based group block data to the bus stops (point layer) that lay within them. If two or more stops fell within the same polygon, the same information was attached to both. The results indicated that the 882 stations generated for the point layer fell into 273 block groups. This process was repeated once again, so that general land use information could be attached to each station. Each station in the database received one of the following designations for land use criteria:

- Commercial
- Industrial
- Mixed Commercial
- Mixed Urban
- Open Space
- Residential
- Transportation
- Urban Vacant
- Vacant Unclassified

Creation of Network Loads

For each bus stop in a route, "load" information was provided by DASH. This variable indicates the number of passengers on the bus, or ridership (subtracting passengers exited and adding those who entered the bus). This variable, therefore, represents network load patterns. This information is useful for assessing the portions of the route, which generate the highest levels of ridership. Given the demographic and land use information associated with each station and its connecting links, the emerging usage pattern can be statistically evaluated.

A network (line layer) was created in Arc View to represent the loading data. This layer was created by connecting bus stops in the order in which they appear in the route. The load value assigned to the line was the load of the bus stop at the beginning of the line. For this purpose another ID was given to each bus stop, similar to the one that had been previously assigned but with a reference to the fact that this was a load. The passenger on and off was cut from the database file, leaving only the load information. The same ID was assigned to the line in the load layer and then was joined in Arc View.

In the end, 60 geographic layers and 60 associated database files were generated, which contained information regarding passenger usage (on, off and total), demographic variables and land use patterns.

GIS Data Analysis

Overall Characteristics

The final database contained 882 stations, overlaying 273 census block groups. The general statistics regarding these stations shows that the number of Midday trips are more than double the PM trips and three times higher than the AM trips. This indicated that the DASH operation caters largely to business activities and might be operating within specific types of land use. Interestingly, while 713 stations are affected by AM trips the difference between Midday and Midday trips is small (806 stations during Midday versus 818 stations during PM). The higher values of stations utilized during Midday and PM peaks once again suggests that DASH's operation is primarily serving an employed population for non-commuting trips. The large standard deviations for Midday "on and off" and the large magnitudes for any single occurrence verify that in fact, very specific stations on specific routes are generating the highest levels of usage. This emerging pattern confirms our initial understanding that trips generated for such micro-level transit service are highly dependent on land use and local variations in demographic characteristics. For this study two levels of analysis were made.

First, assessment will focus on each route, at both station and network levels. This will include classification of the routes by their network load pattern, statistical analysis of station level trips "on and off the buses" and evaluation of the relationship between these trip generation/attraction capacities and various demographic and land use characteristics. Second, in order to understand some of the neighborhood level factors contributing to the usage of community transit services, an analysis of the 273 block groups within which these stations are located will be performed.

Station/Route Analysis and Cartographic Assessment

In order to assess the DASH routes individually, 30 maps were produced depicting the total number of passengers getting on the bus at each stop as well as the total passenger load between stops. After an initial assessment of this map, it became necessary to assess the nature of varying loading patterns according to some exogenous factors such as the land use pattern and demographic characteristics of the neighborhoods surrounding each station. The data indicates that 43.3% of all stations are located within a "commercial and services area" and another 47.3% are located in a "residential" area. This comprises slightly over 90% of all stations. In this light, one might suspect that the primary service of this community transit service is to connect residential to commercial areas (home to work). Given the earlier discussions regarding Midday usage, it is expected that commercial zones would be primarily usage areas. In other words, despite the high number of stations in residential locations, usage (as portrayed by number of trips) is expected to be higher within commercial and service areas.

Investigating Relationships

Basic descriptive statistics allowed for the formation of an overall understanding of the local level transit operation; however, very little in terms of a casual relationship can be expressed in this way. In order to test the role of various independent variables on trip generation and attraction, two hypotheses were proposed:

A. Transit usage is a function of the demographic characteristics of the service areas. This is especially determined by the population composition (percent minorities), age structure, employment levels, per capita income, median household income, education levels and most importantly, population density.

B. Land use plays an important role in generating passenger trips. As such, one would expect that in a commuting-based service, trip origins would be mainly in residential areas and the majority of Midday trips would be generated in high employment/commercial areas. Given this scenario and DASH's mixed usage, two types of routes were expected to emerge: those focused on commuting service (i.e., residential to commercial connection) and those focused on Midday trips (i.e., commercial to commercial connection).

The analysis began with a statistical assessment of the block groups where DASH stations were located. The 882 stations in the study are located in 273 census block groups where 483,628 people live, and where the non-Hispanic White population makes up 50.8% of the total population. Compared to the countywide 41% representation, this data indicates a higher level of service to this portion of the population. However, close examination of the data revealed a different story. Since multiple stations can fall within the same block group, it is important to calculate the number of population served by each station and then add those numbers. This methodology indicates that, while there are more non-Hispanic White neighborhoods on DASH's routes, the number of minorities served, as counted by the frequency of stations, is higher (the mean concentration of African Americans and Latinos served by the 882 stations is 63.86%).

Usage of station level analysis was justified by the fact that within inner-city areas where DASH operates, the impact of individual stations is more important than the overall understanding of the neighborhoods at the block group scale. Using the frequency of stations in a block group as a weight factor in conducting transportation analysis provides a more realistic understanding of the service level and its spatial impact. Also, since land use characteristics vary greatly within a single block group, analysis at the station level is the only accurate method for exploring the relationship between trip generation and land use. In fact, it would be impossible to aggregate the diverse land use categories for a single block group.

The overall demography indicates:
- High minority concentration
- Bimodal education attainment (concentration in less that high-school and college degree)

- Low median household income (mean $28,053, median $21,637 and mode $42,009) and a low per capita income (mean $15,247, median $9,714 and mode $27,623)
- High employment concentration in manufacturing, retail and financial services (this level of employment diversity is caused by the location of routes in central as well as suburban employment concentrations)
- Mainly a working population age

Given the emerging patterns of demographic and land use patterns, two statistical analyses were conducted to explore casual relationships. First, a Pearson Correlation table was created, in which the relationship of demographic variables and passenger loading magnitudes (on and off the bus) were examined. Second, a cross tabulation was run between various land use categories and passenger usage patterns. A Chi-square test was used to measure the degree of association between these sets of variables.

<u>Results of Pearson Correlation (Demography and Transit Usage)</u>

None of the demographic variables produced a viable explanation for the observed patterns of local transit usage. Even after controlling for land use the role of demographic variables remained small. This was especially surprising since population density was expected to explain some of the generated trips. The absence of a satisfactory explanation could be attributed to the fact that while the multiple counting (using the station frequencies) can provide a more realistic measurement of service delivery, block group level analysis (rather than station-based), in which trip origins and destinations are aggregated, can provide a better database for analysis. In order to do this, some recalculation had to occur. The block group level analysis will be presented separately, following a discussion on the impact of land use patterns.

<u>Results from Chi-square test</u>

A cross tabulation was performed on passenger loading patterns and land use at the station level. The results indicate that land use plays an important role in determining the pattern of this community-level transit usage. While both “AM on and off” did not produce a high relationship with land use, “Midday on and off” as well as “PM on and off” and “Total on and off” are highly related to the type of land use where they occur. The low number of stations (30 or less) involved in the Saturday and Sunday trips do not allow for a thorough understanding of their operation beyond what was previously indicated.

<u>Block Group Level Analysis</u>

The complexity of results obtained from the station-based analysis provided the encouragement to conduct a neighborhood-based analysis as well. A primary interest was to determine whether using a spatially focused analysis would produce better results, in terms of correlating trip origins and destinations with some of the available demographic variables. It can be argued that since each station was assigned the characteristics of the census block group in which it fell, and that multiple stations could be located in one block group, a better method for achieving casual understanding would be to reduce the numbers of data repetition (which would reduce the level of correlation and skew the data toward block groups that had a high number of stations within them) and to create a block group data base within which the information regarding trip origins and destinations would be aggregated.

Using the station-based data matrix, 273 block groups were identified to fall on the 30 transit routes in this study. For each of the block groups, the number of stations were aggregated, as well as the AM-Peak, Midday, PM-Peak and Total trips on and off the buses.

The distribution of trips provides an interesting insight into the spatial distribution of this service. With 223 block groups containing some level of "AM Peak" trip origins, an average of 9 trips can be expected. Given the smaller range of 0 to 65, the earlier findings are indirectly confirmed. Trip origins are more diffused than trip destinations. "AM Peak" trip destinations have a much higher range, while their mean is similar to trip origins.

Midday trips are by far the most prevalent. A mean of 26 trips in 260 census block groups is indicative of the importance of this service. Once again, the trip destinations produce a larger maximum value than trip origins, indicating a higher spatial concentration in the former. However, the large magnitudes for both types of trips during the Midday indicates that over 60% of all trips at the census block group level are created during this time of the day, and as such, a higher level of spatial concentration is expected, compared to morning or afternoon.

While afternoon trips are more frequent than morning trips (i.e. means of 12 versus 9), they are spatially less concentrated, especially compared to the morning trip destination (compare maximum values). The higher median value for the afternoon trip destinations combined with a lower maximum value is indicative of a more diffused pattern and a higher dependency on residential areas, a fact clearly illustrated in the previous section.

Saturday and Sunday trips occur in only 10 of the 273 census block groups in this study and are by nature highly concentrated, geographically speaking. The high "maximum" value in all cases indicates that a significant portion of weekend trips occurs in even fewer block groups. For example, of the 109 total trip origins on a Saturday, 51 occurred in one census block group.

Since this database contains the same information as the station-based database, we can continue our test to determine the extend to which the number of trip origins and destinations are related to the selected demographic variables. As opposed to the last test, however, here the neighborhoods will be analyzed, rather than the stations.

Results of the Correlation Analysis

As in the previous section, a bivariate correlation analysis was run on the census block group data. Based on this analysis, AM-Peak trip origins are positively related to education levels, blue-collar jobs, and a younger and working age population. This indicates working inner-city neighborhoods where some trips to work in nearby companies are accomplished by using a local transit provider (also, local transit operation can be used for connecting to regional transit services). Interestingly, since the census bureau data only contains information regarding the residents of an area, AM-Peak trip destinations naturally do not correlate with any demographic variable.

Midday trips are positively correlated with low levels of education and the number of stations in an area. This indicated that census blocks where Midday trips occur are inner-city areas, where a high number of employment/commercial centers are accompanied by a high level of transit service. This is also indicated by more bus stations.

PM-Peak trips are correlated only with the number of stations, and as such indicate that demographic variables provide little impact on the level of trip generation or attraction. This pattern is also obvious in the total number of trips, where demographic variables play a very small role. Only lower levels of education seem to carry their impact at the macro-level for trip origins. This can be interpreted as indicating that in terms of local community transit provision, residential areas are important only where education levels are low and where jobs are within a short distance (most routes do not cover a large geographic region) or when local transit service provides connection to the regional transportation services. For this study, the level of connectivity between the local and regional transit services was not explored.

The results from the correlations began to suggest that local community services provide different types of services in different communities at various times of the day. As such our study had to use a pattern recognition technique that would distinguish various communities based on their demography and levels of trip generation and attraction. This purpose is fully accomplished by cluster analysis, where cases can be aggregated into groups based on their similar characteristics. This approach is especially suited for spatially based planning purposes, where creating zones is fundamental to the adoption and implementation of various urban policies.

For the purpose of this study, the hierarchical cluster analysis methodology was chosen, using “squared Euclidean distance between groups” as a measure of identifying the emerging clusters. Out of the 273 census block groups, only 223 could be used in this analysis (i.e., they were missing no values). Of these, 146 were put in one cluster, 65 in another and the remaining 12 block groups were distributed over 4 other clusters.

The largest cluster (Cluster 1) has a low per capita income, large minority population, low employment average in every occupation and industry, low educational attainment, close to average trip origins and destinations and a more compact/small area. This cluster can be identified as the inner-city transit service area, where trip purposes are mixed.

Using the cluster membership, we also generated a map, which identifies the location of various clusters (the information from the statistical analysis was imported and joined with a block group map in a GIS environment). The map confirms the results, indicating that “Cluster 1” is located mainly in inner-city areas.

“Cluster 6” is the second largest group. These 65 block groups are marked by a higher per capita income and median household income than “Cluster 1”, smaller population and a larger area (which translates to lower average density), a higher proportion of White population, lower levels of young population (under 16), and a more educated population who are professionals in service and retail-oriented jobs. With an equal average number of stations, “Cluster 6” also has a smaller level of reliance on the transit service in this study. This is to be expected from the demographic profile of these census block groups.

The remaining smaller clusters are of special interest. For example, “Cluster 5” which covers only one census block group, has a high population, large number of stations, high median household and per capita income, and a large pool of highly educated population who are employed in entertainment, health, educational and other services. This area, which is located in Pacific Palisades, generates one of the largest numbers of trips. Note that the large magnitude AM-Peak and PM-Peak is comparable to the Midday, indicating a more commuting oriented transit service.

“Cluster 2” covers six census blocks which are characterized by low population densities, high income, advanced educational attainment, high concentration of professionals in service jobs, and a working age population that is more likely to consist of a non-minority population. With the exception of some Midday usage, these six census block groups are marked by one of the lowest levels of reliance on transit service.

“Cluster 3” covers three disjointed areas that are made similar by their high socioeconomic status and lowest transit usage. “Cluster 4” also shares the same characteristics and houses a population with the largest level of income and the highest concentration of a highly educated population that relies only minimally on transit services.

Using the summary data, the clusters can be reduced into 4 groups:

- Inner-city low income areas (Cluster 1), where transit services are highly demanded;
- Inner-city middle-class areas (Cluster 6), where reliance on Midday trips is most prevalent;
- High density suburban locations (Cluster 5), where transit areas provide access to both jobs and other activity centers within the area; and
- Low density areas, where socioeconomic profiles, combined with the widely diffused population, does not allow for high levels of ridership.

Of these, the last group can be seen as a candidate for possible exclusion from a local level of transit service. These areas are typically more suitable for demand-based van services. In the other three clusters, efficiency can be achieved through eliminating and/or reducing AM, Midday or PM services where applicable.

Summary

Midday trips are more than double the PM trips and three times higher than the AM trips. This indicates that the DASH operation caters largely to business activities. The fact that 713 stations are affected by AM trips, while Midday and PM trips affect 806 and 818 stations respectively, indicates that the operation is primarily serving an employed population for non-commuting trips. A cartographic assessment of the routes shows that high loading patterns are associated with commercial and service areas. In spite of the fact that there are more stations in residential locations than in commercial areas, the Midday utilization that dominates these routes centered in commercial areas.

Hypothesis 1 stated that transit usage is a function of the demographic characteristics of the service provided. Based on the correlation analysis, AM-Peak trip origins are positively related to education levels, blue-collar jobs, and younger and working age populations. This indicates inner-city neighborhoods where jobs are located nearby. Since the census bureau data only contains information regarding residents of an area, destinations naturally do not correlate to any demographic variable. Midday trips are also positively correlated with low levels of education and the number of stations in an area. This shows that census blocks where Midday trips occur are inner city areas, where a high percent of employment/commercial centers are accompanied by a high level of transit service. PM-Peak trips are correlated only with the number of stations and therefore, demographic variables provide little impact on the level of trip generation or attraction. Overall, only low levels of education seem to carry their impact at the macro-level for trip origins. These would indicate that local transit is critical to low-income areas to provide transportation to local employers or to regional transit service connections.

Hypothesis 2 stated that land use plays an important role in generating passenger trips. This hypothesis is accepted as being statistically significant for “AM-Peak”, “Midday”, and “Total” trip destinations rather than trip origins. For the “PM-Peak”, the reverse is true. This is associated with the high level of service that DASH provides to concentrated points of interest. Commercial areas, the focal points of interest, carry a significant portion of the trips. There are more stations in residential areas with lower generation/attraction levels. This results in slow collection and mass drop-off characteristics, similar to services provided by buspools and vanpools.

A hierarchical cluster analysis was performed to identify emerging clusters. Four basic cluster categories were found. Cluster 1 is located mainly in inner-city areas and is dominated by Midday trip utilization. Perhaps by working with the MTA, better connectivity could be developed to improve AM and PM utilization.

Cluster 6 is located in areas with higher per capita income and median household income than Cluster 1 and is less reliant on transit services. However, in these inner-city middle class areas, Midday trips are quite prevalent. To increase this Midday utilization, care should be taken to place the stations in areas of commercial need such as near banks, food courts, etc.

Cluster 5 covers only one census group, has a high population, a large number of stations, high median household and per capita incomes, and a large pool of highly educated population who are employed in entertainment, health, educational and other services. Located in Pacific Palisades, it generated one of the largest numbers of trips and utilizes the transit service at all times of the day (morning to evening), indicating a more commuting-oriented transit service. Another possible explanation for the high level of usage in this location is a lack of regional transportation. Because of the high level of utilization, additional stations may be desirable.

Clusters 2, 3 and 4 are associated with high income, well educated, low transit usage areas. Perhaps another type of service such as a community Dial-A-Ride, vanpool or buspool service would be more appropriate in these areas.

GIS and Transit Service Analysis

In the course of this study, it became increasingly clear that GIS would be a fundamental component of any community-level transit service analysis. While creating a comprehensive database can be both consuming and costly, the benefits of such systems can prove indispensable to a small-scale operation that has to rely on a better understanding of travel demands at neighborhood level. As this study illustrated, a number of analytical tasks can become routine when such systems are complete. For example, the simple analysis of loading patterns can offer options for enhancing the service routes and improvements in scheduling individual buses. As data about each route and its associated socioeconomic and land use patterns become available, more robust statistical analysis are possible. Of course, to maintain this capability, a more standardized method of data collection, maintenance and updating becomes necessary. Experience indicates that the cost of maintaining an up-to-date GIS for this purpose can be quite costly, and many smaller transit service providers are unable to bear such expenditures. A creative use of existing GIS facilities in various cities and/or universities could alleviate this problem; however, better models of cooperation are needed.

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TRANSIMS Status: Case Studies

Richard Beckman, *Los Alamos National Laboratory*

Abstract

The Portland case study will be contrasted with the Dallas case study completed in the past. The Dallas study highlighted multiple methodologies for the analysis of TRANSIMS output. The Portland studies are designed to investigate the sensitivity of various output variables to the input data and representations of traveler characteristics, such as high occupancy vehicles, in TRANSIMS.

The planned Portland case study will be described in detail. A series of sensitivity studies on the need for local streets, the machine requirements for running the base case scenario will be described. Additionally, a series of studies to investigate the sensitivity of the environmental module to changing assumptions about the number of transit riders and car pool travelers will be outlined. This will include a discussion of the differences between parametric studies and the “exact” studies usually carried out and the benefits of these parametric studies.

TRANSIMS Status: The Environmental Module

Michael Williams, *Los Alamos National Laboratory*

Abstract

The purpose of the TRANSIMS environmental module is to translate traveler behavior into consequent air quality, energy consumption, and carbon dioxide emissions. The transport, chemistry, and dispersion aspects of this problem are left to EPA's models-3, so the TRANSIMS environmental module focuses on the estimation of emissions. The emission module is driven by results from the microsimulation and the synthetic vehicle population. The synthetic vehicle population is produced from vehicle registration data, the synthetic population and the results of inspection and maintenance tests. The microsimulation produces 15 minute aggregations of vehicles by speed bin along segments of each link. It also gives the fraction of the vehicles that have gaps available to accelerate and the distribution of vehicles entering a link in groups stratified by time-integrated, speed and acceleration product. The microsimulation results are too coarse-grained to be used directly, but they are used with a very small set of empirical relationships to produce fine-grained, distributions of speeds and accelerations of the vehicles in each segment of each link for each 15 minute period.

A modal-emission model transforms the fine-grained, joint distributions of speed and acceleration into emissions of carbon-monoxide, volatile organic compounds, nitrogen - oxides, and particulate matter. In addition the module computes carbon-dioxide emissions and fuel economy. The emissions are estimated for each 15 minute period for each 30 meter segment of each link and the results are provided in a form compatible with EPA's models-3 air-quality modeling system. The light-duty tailpipe module treats tailpipe emissions from cars, small trucks, and sport-utility vehicles. Important aspects include: (1) malfunctioning vehicles, (2) emissions from cold starts, (3) emissions from warm starts in which the engine is still warm but the catalyst is cold, (4) emissions from off-cycle conditions which render the pollution controls inefficient and (5) normal driving. With regard to off-cycle conditions, very high emissions occur at high power demands. The phrase off-cycle refers to conditions outside those that occur in the federal test procedure. Emissions in this context are very sensitive to the precise acceleration that occurs at a specific speed.

The heavy-duty tailpipe module treats tailpipe emissions from trucks and buses. While truck emissions are not as sensitive to demanded power levels as are light-duty vehicles, their emissions are sensitive to the load carried by the vehicle.

TRANSIMS Status: Feedback Studies

Kai Nagel, *Los Alamos National Laboratory*

Abstract

Any transportation model faces the problem that humans do not make all their decisions instantaneously. Instead, they make plans, which they then attempt to execute. For repeated scenarios, such as rush hour traffic, expectations during plans making need to be consistent with the conditions that are encountered during the execution of the plans. For example, if a road that is expected to be empty turns out to be congested, the affected individual is likely to change his/her plans for the following day.

TRANSIMS approaches this problem via feedback. In the simulation, people make plans, all plans are simultaneously executed in a micro-simulation, people change their plans, etc., until some kind of relaxation is achieved. Plans here refers to modal and route choice, but also to activities (such as work, sleep, eat) and their locations. For example, if a network is congested, a stop at home between work and shopping may be dropped. TRANSIMS is designed so that it allows arbitrary methods of feedback.

In my presentation, I will concentrate on examples that we have investigated using the TRANSIMS framework. These examples include route choice, activity location choice, and investigations into the robustness of the results. The examples show that it is possible if desired to use TRANSIMS in a way that closely resembles the 4-step process, but that it also opens the door to a behaviorally much more realistic approach to computational transportation forecasting than the 4-step process allowed.

For example, the TRANSIMS framework allows in principle to model the day-by-day adaptation of a population to a bridge closure. The “feedback problem” is in fact a problem that is pervasive in the socioeconomic sciences. The traditional solution is to assume complete rationality and complete information on the part of each individual. Under these assumptions, everybody knows what everybody else will be doing, and can in consequence compute the global solution (we are assuming uniqueness here for simplicity). This solution is called a (user or Nash) equilibrium because nobody can be better off by unilaterally changing behavior. And since everybody arrives at the same result, it is sufficient to make the computation once and system wide. Traditional traffic assignment models such as EMME/2 are of this type. Demand, in the form of origin- destination-flows, is given. An equilibrium solution is found if no OD flow can reduce its cost by changing paths.

Under certain assumptions, one can show that the problem has a unique solution (in terms of the link flows). In consequence, any algorithm finding this solution is a valid method. Some of the necessary assumptions are: steady-state conditions, link cost a function of demand only, complete rationality, and complete information. As soon as one drops one of these assumptions, or attempts to extend the approach from route choice to, say, activities planning, many of the currently known mathematical foundations break down. As mentioned above, the alternative approach by TRANSIMS and others is to use agent-based modeling together with behaviorally realistic rules on the part of the simulated individuals.

TRANSIMS Status: The Framework And Data Requirements

Brian Bush, *Los Alamos National Laboratory*

Abstract

TRANSIMS (Transportation Analysis and Simulation System) is an integrated system of travel forecasting models designed to give transportation planners accurate, complete information on traffic impacts, congestion, and pollution. This presentation outlines the framework of software modules that constitute TRANSIMS, providing details on their purpose, input and output data, and algorithms. The primary software modules available within the framework presently include: (a) a Population Synthesizer that creates a regional population imitation whose demographics closely match that of the real population; (b) an Activity Generator that creates household activities, activity priorities, locations, and times, and mode and travel preferences; (c) a Route Planner that generates regional individual activity-based travel demand by assigning activities, modes, and routes to individual travelers in the form of trip plans; (d) a Traffic Microsimulator that simulates the movement and interactions of travelers throughout a metropolitan region's transportation system; (e) an Emissions Estimator that translates traveler behavior into consequent air quality, energy consumption, and pollutant emissions; and (f) an Output Visualizer that allows an analyst to view and animate data generated by any of the other modules. A special unit of software, the TRANSIMS Selector, holds the framework together by controlling when modules are run and how the data are routed between modules.

TRANSIMS Status: Commercialization and Deployment

Christopher Barrett, *Los Alamos National Laboratory*

Abstract

Over the next year and a half TRANSIMS is to be commercialized. The commercialized version of TRANSIMS, called TRANSIMS-DOT, is the version that is to be released to MPO's. This process of commercialization will be described. This will include the status of pre-proposal meetings and the expectations of both the Department of Transportation and the Los Alamos National Laboratory. Additionally, the calendar of events leading to the selection of trial MPO's for first TRANSIMS-DOT use will be outlined.

TRANSIMS-DOT will be contrasted with the research version of TRANSIMS, TRANSIMS-LANL. TRANSIMS-LANL will be released under license agreement to researchers, but not for commercial use. The process for obtaining the research code TRANSIMS-LANL and the license requirements will be illustrated.

Exploring Variations In Travel Behavior

Patrick J. Costinett, *Parsons Brinckerhoff Quade & Douglas, Inc.*;
and Michael Gillett, *Oregon Department of Transportation*

Abstract

The Oregon Department of Transportation, in cooperation with MPOs throughout the state, is conducting a major model improvement program. The program includes extensive surveys and new models for land use and travel demand forecasting encompassing statewide, regional, and urban area models. This paper presents results of an analysis of household travel surveys conducted throughout the state.

Activity-based household surveys were conducted in the Oregon MPO areas of Portland, Salem, Eugene-Springfield, and Medford yielding results for over 11,000 sample households. The Portland Metropolitan area survey also included Clark County, Washington. A separate sample focused on satellite cities and suburban areas outside the MPO boundaries. In addition, over 3000 households were surveyed in eight primarily rural counties across the state. Each household was surveyed on two consecutive days yielding a total sample of almost 30,000 household-days.

While a survey of this magnitude has many uses at both the local and statewide levels, this paper focuses on statewide travel demand estimated from the survey and variations in travel demand patterns throughout the state. It is based on analyses designed to support development of a statewide integrated land use-transportation model and a unified approach to travel forecasting in smaller urban areas. The paper also describes the design and organization of the household activity survey program and efforts to achieve consistency in survey results throughout the state.

The nature and magnitude of variations in travel demand characteristics within Oregon is a major concern in developing travel forecasting models. Typically, good information on such variations is lacking. The breadth and depth of the surveys conducted for Oregon provide a rich basis for exploring travel demand characteristics and testing related hypotheses. Analysis and findings presented in the paper deal with the following facets of direct relevance to travel demand modeling:

- Stability of trip generation rates by household cross-classification, by trip purpose and area type
- Stability of trip attraction rates and composition, by trip purpose and area type
- Stability of trip distribution parameters, by trip purpose, by area type and size
- Stability of auto occupancy rates, by trip purpose, by area type and size

The consistency of survey design and conduct, the common time frame across all the surveys (1994-96), and the coverage across all areas of the state provide a unique opportunity for the exploration presented in this paper. Findings are especially relevant to the transferability of model parameters from one area to another and to the feasibility of standardized modeling approaches.

Travel Time Data Collection Using GPS

Robert McCrary and Charles Hodges, *Pima Association of Governments*

Abstract

The Pima Association of Governments (PAG) has initiated a travel time data collection program using the global positioning system (GPS). Travel time based performance measures are replacing the traditional volume/capacity based measure for evaluating peak hour congestion. In addition, these data are helping adjust default capacity tables to better reflect local conditions, and they will help calibrate the regional transportation model.

An on-going update to the Congestion Management System (CMS) served as a catalyst for change. The persistence of anomalies in the LOS estimations led to scrutiny of the underlying methodologies. A literature review confirmed that traffic volumes have only a moderate correlation with travel speeds (the standard for arterial LOS), and the experience indicated that estimating capacity was also problematic. Because a 1997 FHWA-sponsored pilot project in our region had proven the efficacy and economic efficiency of using GPS to collect travel time data, the multi-jurisdictional committee overseeing our CMS decided to adopt travel time related performance measures for assessing the extent and duration of system congestion.

Travel time data for twenty-one different corridors are being collected with differentially corrected GPS during the PM travel peak. The "floating car" method is used, but with fewer runs necessary for equivalent data accuracy compared to manual methods. Added to an existing database collected since 1997, these data are being translated into system performance measures at different temporal and geographic scales of analysis. Due to resource constraints, traditional LOS will be retained for average daily travel and unsampled roadways. Poor levels of service may serve as a "trigger" for initiating additional travel time studies. Travel rates are expressed at the corridor scale, more closely relating to the actual commuter's experience. More analytical applications will use statistically tested average travel times and delays at the link scale of analysis.

Link travel times are very important both as a replacement for the LOS paradigm, and as a rich database for inferring typical values across the system. The former application will use average run speeds in ratio with travel speeds to define qualitative thresholds. The latter uses run speed per mile and delay broken down by functional roadway sub-class as a means to refine capacity tables and LOS determination. These field data will also be used to refine scenarios for calibration for the regional model. Targeting congested intersections for travel time data collection and subsequent analysis will enhance air quality modeling. Implementation of this plan is concurrentn with some on-going research elements, and a study report will be an addendum to the draft CMS in December 1998.

Quality field data are always in short supply in transportation planning. GPS is allowing our MPO to improve both the quantity and quality of our information in a cost-effective manner. An effort is underway to disseminate this information to the public. PAG expects that alternative, travel time based performance measures and capacity refinements will bring greater depth and reliability to our technical analyses, and improve the quality of transportation planning for the public and our member jurisdictions.

Weaving Section Analysis Using Video License Plate Surveys

David P. Moffett, *Purdue University*

Abstract

Weaving section analysis is a difficult, data-hungry process that is difficult to execute. The described methodology uses existing video license plate survey mechanisms to develop the data needed to do such an analysis.

Introduction

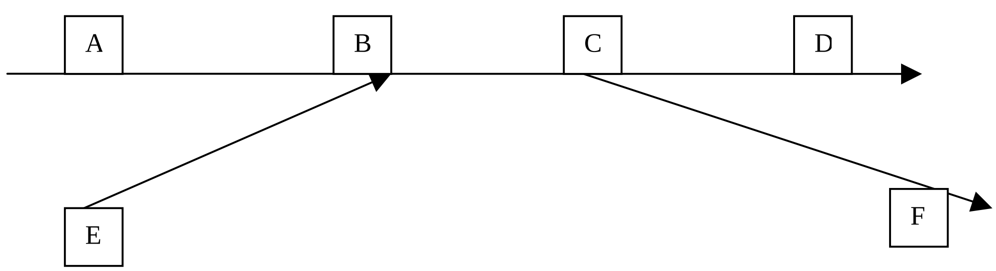
As the US Interstate highway system reaches the end of its pavement life much of it is undergoing substantial re-design and re-engineering. Part of that redesign depends on an understanding of how the system is used and where potential trouble spots are located. One potential problem is intersection to intersection weaving where one flow of vehicles must intertwine with another flow in a short distance and/or short period of time.

One way of computing the weaving activity between two points is to conduct a license plate survey of all vehicles entering and leaving the section being studied. The following procedure cuts this need to just those vehicles entering and leaving via the ramps that create the weaving.

Methodology

First a sample map to provide a frame of reference.

Figure 1 – One Interchange



Vehicles enter the study area from either point A or E. They exit from D or F. The weaving area that is being considered is between B-C, where a stream of vehicles from A wants to exit at F crosses the stream of vehicles entering at E and continuing at D. The goal is to determine the flow A-F against the flow E-D.

Table 1 – Sample plate routes

Plate Name	A to D	A to F	E to D	E to F
P1	**X**			
P2	**X**			
P3	**X**			
P4	**X**			
P5		**X**		
P6		**X**		
P7		**X**		
P8			**X**	
P9			**X**	
P10				**X**

Table 2 – Counts per station

Station	Count
A	**7**
D	**6**
E	**3**
F	**4**

So 4/7^{ths} of the vehicles seen at A are through trips to D, while 3/7^{ths} become part of the weaving as they get off at F. Further, 2/3^{rds} of the vehicles seen at E continue on at D and thus are part of the weave, while 1/3rd immediately get back off at F.

Viewing this problem as only looking at vehicles from E and going to F is the trick. At E three vehicles were observed (P8, P9 & P10) and at F four were seen (P5, P6, P7 & P10). Knowing that one vehicle was seen going from E to F and that can be removed, then by process of elimination 2/3^{rds} of the vehicles seen at E (three seen minus the one E-F divided by three seen) were in the weave. Similarly 3/4^{ths} of the vehicles seen at F (four seen minus the one E-F divided by the four seen) were the opposite movement in the weave.

Thus, in this tiny example, two weave with three in the section B-C over the period that the data was collected.

Having now seen how this is done, setting up video cameras at both E and F allows the computation of the weaving movements on the main line. All one need do is subtract off those vehicles that are not active in the weave.

The data in Table 1 can be summarized in two more ways.

Table 3 – To/From Table

From \ To	D	F
A	**4**	**3**
E	**2**	**1**

Of course, A->D data isn't needed, so Table 2 could just as easily be:

From \ To	D	F
A	**Don't Care**	**3**
E	**2**	**1**

Or instead of looking at raw counts, the percentages could be used.

Table 4 – *To* Percentage Table

From \ To	D	F
A		
E	**66%**	**33%**

Thus 66% of the vehicles seen at E went *to* D, while 33% of the vehicles seen at E went *to* F. Obviously, since there was no data collected at A, the total volume is unknown and thus computing percentages isn't possible.

Similarly, the 'From' case has a table:

Table 5 – *From* Percentage Table

From \ To	**D**	**F**
A		**75%**
E		**25%**

And 75% of the vehicles seen at F came *from* A and 25% came *from* E.

Percentages are useful for several reasons. First, usually counts are done in cooperation with the Video License Plate Survey, but not on the same day. When the actual weaving movements are computed, they'll need to be reconciled with the counts, so using percentages is a good way to reconcile the differences between two similar but not identical periods of data collection. Percentages are also useful in dealing with the vehicles where their routes couldn't be established.

In doing real analysis, it turns out that often the trips of some percentage of vehicles do not have their routes successfully captured. These are 'lost' vehicles in the language of license plate matching. Here is an example of this problem, using the same route map (Figure 1).

Table 5 – Sample plate routes with unknowns

Plate Name	A to D	A to F	E to D	E to F	E only	F only
L1	**X**					
L2	**X**					
L3	**X**					
L4	**X**					
L5		**X**				
L6		**X**				
L7		**X**				
L8			**X**			
L9			**X**			
L10				**X**		
L11					**X**	
L12					**X**	
L13						**X**

Table 6 – Counts per station with missed matches

Station	Count
A	**7**
D	**6**
E	**5**
F	**5**

And in the summary trip table, it becomes:

Table 7 – To/From Table

From \ To	D	F	Lost
A	**Don't Care**	**3**	
E	**2**	**1**	**2**
Lost		**1**	

There are several things that can be done at this point. The first is ignore the problem (given the number of unmatched is small) and go on to percentages as usual. If percentages are not going to be used, then the ratio of known vehicles can be used to distribute the trips as follows.

Table 8 – Revised To/From Table

From \ To	D	F	Lost
A	**Don't Care**	**3 + 0.66**	
E	**2 + 1.33**	**1 + 0.33 + 0.66**	**0**
Lost		**0**	

Here the trips from the unmatched are redistributed back onto the known counts. For E-D, the 2 trips were original and the 1.33 trips are 2/3s of the two unmatched 2 (the numerator 2, from the original E-D count and the denominator from the original counts E-D (2) and E-F (1) being added up). The E-F value is the original count of one plus 1/3 of the F column lost (1) that is 0.33 plus 1/3 of the E row lost (2) that is 0.66 for a total of 2.

Table 9 – Cleaned up To/From Table

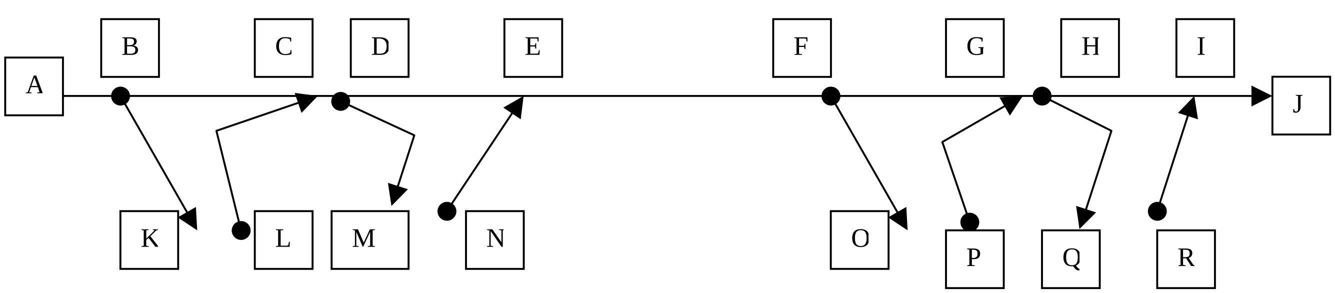
From \ To	D	F	Lost
A	**Don't Care**	**4**	
E	**3**	**2**	**-**
Lost		**-**	

And then the partial vehicles are rounded back to integers. It is useful to understand that at this point the total plates seen at all locations (i.e. E+F) has changed from 10 to 9 due to rounding. In terms of percentages on little used facilities, these rounding results can change the net percentages considerably. The analyst needs to be cognizant that this can happen if blindly processing the output from a computer matching run.

More Complex Scenarios

Similarly, more complicated interchanges can be done all by the correct addition and subtraction. Figure 2 represents one direction of two adjacent interchanges. Typically these are located very close to each other so weaving in sections C-D, D-F, E-G, and G-H are of interest.

Figure 2 – Two Interchanges



A similar method is used to compute these sections. Data is taken on links LC, DM, NE, FO, PG and HQ. Then these data are used to compute the following weaving sections:

Table 10 – Computation of Complex Weaving Sections.

Section needed	Method
C-D	As before, LC (minus those going on to DM) makes up the on-bound flow while DM (minus those coming from LC) makes up the off-bound flow.
D-F	Part 1 of this segment is the DE that has no new flows but the flows 'continuing' from LC intermixing with mainline flows. Part 2 of this segment is the addition of NE flows. Thus the on-bound flows are those from NE minus those also seen at FO. The off-bound flows are those seen at FO minus those also seen at NE. Obviously this can be expanded in either direction. Either up stream to include the additional vehicles introduced by LC or down stream by those further exiting at HQ. An up-stream expansion would then be on-bound flows are those from LC and NE with LC loosing both DM and FO common vehicles and NE loosing just FO common vehicles. Off-bound flows then would be at DM just those seen at DM less those also seen at LC and at FO all those seen at FO less those also seen at LC and NE.
E-G	Part 1 of this segment has the addition of flow from NE. Part 2 has no new additions. This then degenerates to a simple example much like before with CD. NE (minus those going on to FG) makes up the on-bound flow while FO (minus those coming from NE) makes up the off-bound flow.
G-H	As before in CD, PG (minus those going on to HQ) makes up the on-bound flow while HQ (minus those coming from PG) makes up the off-bound flow. If need be (due to geometric reasons), the flows from NE can be added with those departing at FO subtracted off.

Comments & Extensions

The proceeding provides the framework to use video license plate survey information in a different framework than just a 'simple' O-D survey.

It is important to note this is a video survey because it matters that each vehicle is recorded, even if it's ultimate destination is unknown. Further the matching code that has been used on all the projects this methodology has been applied to exploits the complete-plate nature of video surveys.

Peak periods are done by sub-setting the data by time. Since the 'study area' is very short, it is easy to say vehicles seen between 4:45 P.M. and 5:45 P.M. make up the peak period and just those data are used. If the net area being studied were larger, then travel time would need to be taken into account. Since even in Figure 2's network, the total travel time will be under 120 seconds, travel time isn't an issue.

Sometimes vehicle classification is needed in such surveys as the weaving characteristics of trucks differ from that of automobiles. If each vehicle is coded by its classification as it is transferred from video, then it is a simple matter to segregate the truck weaves versus the auto weaves by a similar means as is done by time period.

How to handle data outages, and other video license plate survey issues that are not specific to weaving are the subjects of other work the author has done.

Future

Video License Plate Surveys are made up of several steps:

1. Study Design – The type of data needed is determined then the safe location of each point where data is collected is decided and marked.
2. Data Collection – Cameras are set up at the locations determined in Step #1 and data is collected. For weaving studies, typically 12-14 hours of data is collected per camera.
3. Data Reduction – The tapes are watched and files are created for each tape noting the location, plate, vehicle type and time.
4. Analysis – Matching is done along with analysis such as that described herein.

Work currently underway at Purdue University (contact fricker@ecn.purdue.edu or the author) to reduce the costs of step #3 by having a computer read plain VHS videotape directly to a file. At present humans watching each tape do this step and record each vehicle as it goes by. Since Data Reduction takes as much as 50% of the total budget of such a study, it is hoped that this will result in a net cost reduction of as much as 1/3 of the total cost of one of these studies. Others (see, for example, Paul Shuldiner at University of Massachusetts, Amherst) are already having some success automatically reading higher quality video sources.

Acknowledgements

This work is the by-product of an initial query around 1990 by Jon Fricker of Purdue University about automating the data analysis phase of a manual license plate survey.   After several iterations, the matching code found its way into production with Bernardin, Lochmueller and Associates, Inc. doing origin-destination work for the State of Indiana in first in Kokomo, Indiana and later in many other locations in Indiana and Kentucky.   After the O-D surveys, the problem of computing weaving sections and related 'micro' area matchings appeared and this methodology was developed. It has been applied to four major Indiana interstate locations.

This paper has not been reviewed by Bernardin Lochmueller, INDOT or Purdue University. It does not represent the views of anyone but the author.

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Heavy Duty Truck Activity Survey Using Global Positioning System (GPS) Technology

David P. Wagner and John P. Seymour, *Battelle Memorial Institute*; Elaine Murakami, *Federal Highway Administration*; and John Nguyen, *California Air Resources Board*

Abstract

The California Air Resources Board and the Federal Highway Administration have joined with Battelle in conducting a study of medium- and heavy-duty trucks being used in the transport of goods and providing services. This two-year program uses satellite positioning (GPS) technology to characterize the activity in five weight classes of trucks. Specifically, information is being collected on the average number of starts per day, average speed per trip, average duration at idle per trip, and percentage of time at various speeds by regions of the state. This data was previously obtained by roadside-driver surveys and was of questionable accuracy or using trip recorders that are much more intrusive. The information will be used by these agencies in improvement of their respective vehicle emissions inventory models (which are used in predictions of air quality) and to better understand congestion/route patterns.

Since the California truck population is in excess of 661,000 vehicles, obtaining a representative sample of the various trucks is a problem. The sampling approach pursued an opportunity sample of trucks throughout California as the means of describing truck activity. The resultant data base contains 136 samples (trucks) that accumulated over 86,000 miles of travel throughout California.

Results from the analyses include speed profiles, trip start and stop patterns, and soak times by truck weight class and geographic distribution of the truck activity. This paper reports on the sampling approach for truck activities, describes the data set obtained during the course of the project, and presents results from analyzing the data set. The data collection equipment and methodology, problems encountered, and suggestions for future applications are described in detail.

Impacts of Special Event Ridership

Maria E. Amador, *Multisystem, Inc.*

Abstract

Rail and light rail systems with stations adjacent to convention centers, arenas, stadiums and other sporting event facilities experience fluctuations and increases in ridership resulting from the events held at these facilities. These fluctuations and increases affect not only average weekday, Saturday, and Sunday ridership but also ridership by time of day. The impacts of these fluctuations need to be understood and considered when ridership forecasts are developed for new systems and for extensions of current systems.

In an attempt to determine the impacts of special event ridership on Bi-State's Metrolink, ridership on days when special events were scheduled was analyzed and compared to the ridership on non-event days. The analysis attempted to identify three impacts: 1) overall impact of special events on average ridership for weekdays, Saturdays, and Sundays; 2) overall ridership impacts of different types of events; and 3) impacts of special events on ridership by time period. The analysis on the overall special event ridership impacts and the events by category were conducted using 12 months of data. The impacts on ridership by time period were conducted for two typical months. The events were grouped into the following categories: football, baseball, hockey, soccer, college basketball, concerts, and family performances.

The results of the analysis indicated that on average special event ridership accounted for 7% of weekday, 11% of Saturday, and 23% of Sunday ridership. By event category, baseball was found to have the largest total ridership impact; but football was found to have the largest average day impact. Average event ridership estimates by event category ranged from over 18,000 boardings for football games to 2,600 boardings for soccer games. The analysis of the distribution of ridership by time period indicated that special events impacted midday, p.m. peak and evening ridership, with the greatest impact occuring in the evening ridership.

Although these results are specific to Metrolink, the magnitude of the impacts on the daily and time period ridership indicate the need to reflect special event ridership on ridership forecasts. These impacts, however, usually cannot be projected with most travel-behavior models. Planners need to collect this data and account for special event ridership in their forecasts.

TIP Online

Lore Watt Corradino, *Southeast Michigan Council of Governments*

Abstract

TIP Online is a searchable tip data base located on SEMCOG's web page. Developed to provide basic transportation planning information to the general public, TIP offers web page visitors the opportunity to "see what's happening" in their own communities and to tell us, using an e-mail response form, what they like and don't like.

TIP Online makes it possible to do a simple search for specific projects by year, county or street name or a complex search (using boolean logic) to focus on a specific area or time period. General project descriptions plus project cost and sponsor are included as background information. Results of the search can be viewed on the screen or printed.

Immediately following TIP Online's debut, almost 2,000 visits were made to TIP yielding more e-mail responses and phone calls from citizens than the agency has ever received. For most respondents, this was their first time they have ever called SEMCOG or any transportation agency.

In addition to reaching many "first timers", the TIP Online project proved to be more valuable than imagined because:

- We reached several people who are physically challenged and use the Internet to get news and communicate with others,

- TIP Online became a quick reference for TIP projects. Often we receive phone calls from another agency regarding a project and they are referred to TIP Online,

- TIP Online's search feature makes it easy for SEMCOG planners to quickly lookup projects. This is much easier than the traditional "thumbing" through the printed document.

TIP Online is easy to update and information regarding the amendment process and proposed projects is easy to modify and include in the central TIP data base.

Although successful, TIP Online does need improvement. Currently the data base is project specific and fails to relate the projects to the region's needs. During the next year the data base will become searchable by regional transportation goals.

HUBLINK: A New Approach to Mobility for Western New York

Larry S. Englisher, *Multisystems, Inc*.; and Karen J. Rae,
Niagara Frontier Transportation Authority

Abstract

This presentation describes the analysis process and public involvement that led to the adoption of the HUBLINK plan. The plan was developed through a one-year study of service and organizational restructuring of public transportation in Western New York. The Niagara Frontier Transportation Authority commissioned this study to respond to changing demographics and travel patterns, increasing needs among new market segments, declining ridership on traditional services, federal and state welfare to work initiatives, and increasing funding constraints. The study was guided by NFTA's newly mission of "optimizing mobility through cost-effective, quality transportation services." The study included market research, technical analysis of transit services, coordination analysis and financial planning as well as an extensive public participation program.

The result of the study is a comprehensive mobility plan for the region that builds on the strengths of the existing public and private service networks and introduces new types of services to meet the differing needs of urban, suburban and rural areas. The plan envisions new partnerships among public operators, private for-profit and non-profit carriers, sponsoring human service programs and funding agencies, universities, employers and business interests, federal and state departments and local municipalities. These partnerships were forged during the study as part of the very successful stakeholder outreach program.

The mobility plan calls for an urban core system of bus, rail and ADA paratransit, a regional bus system, a system of hubs or transit centers,local circulation services using small vehicles, a coordinated network of special market services, a ridesharing program and other supportive services. The local circulation services would include innovative flexible services funded in part by local entities. A Mobility Coordinator is proposed to serve as a broker for all small vehicle services, arranging purchase-of-service agreements between sponsors and carriers and providing ridesharing services and marketing.

Application of an Analytical Hierarchy Process at the Indiana Department of Transportation for Prioritizing Major Highway Capital Investments

Kyeil Kim, PhD & Vince Bernardin, AICP, *Bernardin, Lochmueller & Associates, Inc.*

Abstract

This paper presents a paradigm for generating models that can be used by planners and decision-makers for prioritizing a list of transportation projects. First, the former prioritization system maintained by the Indiana Department of Transportation (INDOT) is outlined for its features, strengths, and weaknesses. Then, a decision-making methodology known as "Analytic Hierarchy Process (AHP)" is introduced and a decision model using AHP is developed for a sample list of expansion projects under consideration by INDOT. Later, the computer implementation of this process using Expert Choice® software is demonstrated. At the end of this paper, the former system is tested for its efficiency in project ranking processes, and a revised list of prioritization criteria is recommended based on findings from a series of sensitivity analyses.

Introduction

Limited financial resources for implementing transportation projects impose a need for systematic planning, policy, and investment decisions leading to a prioritized listing of prospective projects. Often, those decisions are made with arbitrary and unstructured judgments, misleading analyses, or incomplete information. One approach to avoid the "ambiguity" in decision-making is to move towards a formal Decision Support System (DSS) for the determination of socioeconomic, environmental, and transportation impacts and the assessment of proposed projects through mathematical modeling [*1*]. The DSS is an interactive, computer-based system that helps decision-makers utilize model-based, data-based, and display-based components to solve unstructured and ambiguous problems [*2*].

Within the framework of the DSS, this paper presents a methodology to prioritize a number of highway projects. This research was conducted in the context of a contract with the Indiana Department of Transportation (INDOT) to improve the statewide transportation planning process in 1998 [*3*]. This aspect of the study focused on evaluating/improving INDOT's decision support system used for prioritizing major capital improvements to the transportation system. This research implemented the statistical procedure known as "Analytic Hierarchy Process (AHP)" for prioritizing highway projects through the assessment of both qualitative and quantitative criteria associated with the projects. This paper briefly describes major aspects of the study addressed in the research, as summarized in the following:

- Description, strengths, and weaknesses of the former prioritization process in INDOT
- Introduction to AHP (theoretical background, case study, and computer implementation)
- Sensitivity analysis for the former prioritization process
- Recommendation of a Revised INDOT Prioritization System

Description of the Former Prioritization Process

The former selection and prioritization process utilized by INDOT is based on a spreadsheet process and assesses proposed expansion projects in terms of nine criteria, which are:

- the fatal accident rate,
- the volume/capacity ratio,
- potential economic benefits or losses,
- harmful environmental impacts or opposition,
- conformity to local plans,
- the viability of non-highway modes,
- geometric adequacy,
- growth potential, and
- whether or not the project provides a missing link in the system.

For expansion projects, the scores on these nine criteria are entered into an EXCEL® spreadsheet by following the pre-defined rules of scoring. The scores on each criterion are converted to relative percentages among the projects with respect to the highest scores of the project that are given to 100%. The system then weighs the percentages associated with each criterion by a pre-established value reflecting the relative importance of the factor as determined by a survey of INDOT central office and district staff. The weighted percentages are then summed. These cumulative values are then ranked from highest to lowest priority.

Strengths of the Former Prioritization Process

This system represents INDOT's first systematic approach for prioritizing expansion projects in recent history. One of the strengths in this system includes a multi-factorial approach. The system identifies nine criteria as factors to determine the overall project values, which reflect knowledge and experience of INDOT central office and district staff. These criteria encompass both qualitative and quantitative assets of the project. The system also provides a collaborative process of data collection and value ratings. The process is easy to implement, and provides virtually no limitations in the number of criteria or projects. On the whole, it conceptualizes the overall prioritization process for the expansion projects, and as such, it is a major step forward.

Weaknesses of the Former Prioritization Process

Despite its strengths, the system has certain deficiencies.

- The system violates a principle of statistical analysis by treating ordinal data (i.e. qualitative) as measurable (i.e., interval or ratio scale) data. Using absolute values of the ordinal data rather than relative ones and including them with quantitative data in the same equation of ratings is problematic.
- The system considers only the degree of need for an improvement and certain of its impacts. It does not measure the effectiveness of the proposed improvement at correcting the perceived problem, much less the cost-effectiveness. In other words, it can be viewed as a diagnostic and descriptive tool, but not a prescriptive one.
- Key input values are not always reliable. For example, one person's assessment of whether or not a project may have an adverse environmental impact may differ from another's.

- The system adopts too many criteria that minimize the effect of each criterion on project ranking.

Analytic Hierarchy Process (AHP)

As an alternative to the former spreadsheet-based prioritization system, this study suggests a decision-making methodology that uses Analytic Hierarchy Process (AHP) methods. The AHP eliminates the statistical problem underlying the current spreadsheet approach. The AHP is a decision-making tool for complex, multi-criteria problems where both qualitative and quantitative aspects of a problem need to be incorporated [*4*]. In AHP, the important components of a decision problem are decomposed into a hierarchy of a goal, criteria, and alternatives, as shown in Figure 1. Then, the decision-maker implements a series of simple pairwise comparisons of the elements in the structure, and those comparisons are used to develop overall rankings of the alternatives.

AHP is a simple concept that makes use of fundamental principles of matrix algebra. This process was developed more than 20 years ago and continues to be the most highly regarded, mathematically proven, and widely used decision-making theory in use. Despite broad application of AHP in many industries such as manufacturing, medical, military, etc., it has not been used extensively in transportation planning decision-making although it lends itself perfectly to the problem.

The ultimate tasks in AHP are to obtain "eigenvectors" and "eigenvalues" for the problem in order to estimate the relative rankings of alternatives within an acceptable range of consistency. An eigenvector is computed to determine priorities of alternatives, and an eigenvalue to measure any inconsistencies in pairwise judgments.

Theoretical Background of AHP

In the hierarchical structure of goal-criteria-alternatives, assuming that the goal is to assess n alternatives (e.g., highway projects) based on m criteria, the AHP completes the following steps to achieve the goal:

<u>Step 1: Calculation of eigenvector for criteria</u>

a. In AHP, the elements of the hierarchical model are evaluated by making pairwise comparisons. A pairwise comparison assesses the relative weights associated with two criteria, a_{ij}, in terms of their importance for achieving the goal. Thus, the AHP necessarily establishes the overall comparisons into a two-dimensional matrix. The weights a_{ij} are defined by the following rules:

    - If $a_{ij} = \alpha$, then $a_{ji} = 1/\alpha$
    - If two elements are judged to be of equal importance, then $a_{ij} = a_{ji} = 1$
    - $a_{ii} = 1$ for all i

    In our example, the comparison of m criteria results in an $m \times m$ matrix as follows:

$$\begin{matrix} Criteria \\ Matrix \end{matrix} = \begin{pmatrix} 1 & a_{12} & . \; . & a_{1m} \\ 1/a_{12} & 1 & . \; . & a_{2m} \\ . & . & & . \\ & & 1 & \\ . & . & & . \\ 1/a_{1m} & 1/a_{2m} & . \; . & 1 \end{pmatrix}$$

b. Once the criteria matrix has been formulated, the matrix needs to be investigated for the degree of consistency in pairwise judgments. The meaning of "consistency" can be easily exemplified as follows: If Apple A costs 4 times more than Apple B and that Apple B costs 3 times more than Apple C, to be perfectly consistent Apple A costs 12 times more than Apple C. The consistency among judgments involving a number of elements can be examined with the same kind of logic.

The degree of consistency is measured by a Consistency Index, or C.I., through the computation of eigenvalues. To compute an eigenvalue for the criteria matrix, let A be the $m \times m$ pairwise comparison matrix. Then, eigenvalues of A are λs that satisfy the equation $det[A-\lambda I] = 0$, where I is an *identity matrix*. Of these eigenvalues, the largest value of eigenvalues, λ_{max}, is used to calculate C.I. as shown in the following equation. C.I. equal to 0 means perfect consistency in pairwise comparison, and C.I. greater than 0 implies some inconsistency in judgment.

$$C.I. = \frac{\lambda_{max} - m}{m - 1}$$

c. An eigenvector can be estimated in various ways with slightly different results from one another. However, the exact solution is obtained by raising the comparison matrix to arbitrarily large powers and dividing the total of each row by the total of the elements of the matrix. This matrix manipulation results in an $m \times 1$ matrix, which contains relative rankings of criteria.

Step 2: Calculation of eigenvector for alternatives (i.e., highway projects)

Following the same procedures as Step 1 yields an $n \times 1$ matrix as a result of pairwise comparisons between alternatives with respect to each criterion. Arranging each of the $n \times 1$ eigenvectors to the respective column of criterion produces an $n \times m$ matrix, which consists of vectors of priorities for n alternatives with respect to m criteria.

Step 3: Calculation of overall ranking of alternatives

To obtain the overall ranking of the alternatives, an $n \times m$ matrix from Step 2 is multiplied by an $m \times 1$ matrix from Step 1. This matrix multiplication results in an $n \times 1$ matrix, which contains the overall standing of the alternatives.

Example of Prioritization Process for 2004 Expansion Projects

The goal of this example is to set priorities for selected highway projects in Indiana using the AHP procedures. Table 1 contains a list of 17 projects along with 9 criteria affecting their prioritization. The table cells contain the project-related data associated with each criterion. The criteria and respective data have been extracted, without any modifications, from the report, "2004 Expansion Projects: Selection & Prioritization Process" dated June 1996 written by the Division of Planning and Programming at INDOT.

<u>Calculation of eigenvector for criteria</u>

In order to obtain an eigenvector, criteria are compared in a pairwise manner and these comparisons result in a 9×9 matrix. Matrix manipulations using this matrix yield an eigenvector for criteria as shown in Table 2.

<u>Calculation of eigenvector for expansion projects</u>

The next step is to evaluate all the projects and to obtain vectors of priorities on each criterion. The computing procedures taken to calculate an eigenvector for criteria are also applied in this step, except that we have nine 17×17 matrices of the projects for the criteria instead of a 9×9 matrix of criteria. Table 3 summarizes eigenvector results for the projects in terms of their respective criterion.

<u>Calculation of overall ranking of projects</u>

The overall ranking of the projects is established by multiplying the eigenvector for the projects in Table 3 by the priorites for criteria in Table 2. This multiplication results in a 17×1 matrix, which contains the rank of each project, as shown in Table 4. For comparative purposes, the fourth column of the table shows the project rankings that were generated from the former rating system.

AHP using Expert Choice®

Expert Choice® is a computer tool designed to facilitate the overall processes inherent in AHP [*5*]. Utilizing the built-in user interface modules, the decision maker is able to set the goal, criteria, and alternatives in a hierarchical tree. Then, Expert Choice® leads the user to compare pairs of elements of criteria and alternatives, and these comparisons are then synthesized to determine relative rankings of alternatives. Figure 2 shows an actual screen in Expert Choice® that contains a hierarchical model for the 2004 expansion projects.

Expert Choice® allows the user, for each pair of judgments, to select the type of comparison, i.e. Importance, Preference, or Likelihood, and the mode of comparison, i.e. Verbal, Numerical, or Graphical. In addition to these types of comparison, the user is also able to enter actual data for the quantifiable data. Based on inputs from the user, Expert Choice® computes eigenvectors for both criteria and highway projects, and yields overall priorities of projects as shown in Figure 3.

Sensitivity Analysis for the Former Prioritization System

In this section, a series of sensitivity analyses is implemented for the former INDOT prioritization system in order to investigate the effectiveness of the system with nine criteria in project ranking.

In the former prioritization system, certain of the criteria weights are very small relative to other weights. This fact gives rise to doubts about the effectiveness of these criteria in influencing the ranking process. Sensitivity analysis is used to examine how sensitive the rankings of the projects are to changes in the weights of the criteria. Figure 4 shows the overall priorities of projects along with the current weights of criteria. As the first scenario of the sensitivity analysis, the criterion with the smallest weight, i.e., Intermodal Alternatives, is eliminated and the subsequent effects on the rankings of the projects according to the elimination are noted. When this analysis is conducted, *there are no changes in the rankings.*

In the second scenario, the criterion with the second smallest weight, i.e., Missing Link, is eliminated while INTM remained in the criteria list. *This scenario also shows no changes in the rankings of the projects.* It can be inferred from these analyses that the weights of the two criteria are so small that they impose negligible impact on the project rankings. This interpretation further leads to the following questions: "What is the minimum weight of a criterion to be meaningful in the project ranking process?" In order to clarify this question, an attempt is made to investigate a threshold weight for the smallest weighted criterion INTM, as described in the following.

In Figure 5, the solid vertical line represents the weight of the criterion selected for the X-axis of the graph, and the slanting lines represent the linear relationships among the projects with regard to the weight selected for the X-axis. The current weight for the criterion is where the solid vertical line intersects the X-axis, 0.047 or 4.7% of INTM in this graph. The priorities for the projects are the Y-axis readings where the solid vertical line intersects the slanting project lines. The point at which the project lines cross one another is a "threshold point" where the preferred project with respect to the selected criterion changes. The threshold point is indicated as the point "A", and the corresponding weight of the criterion INTM is the X-axis reading, .123 or 12.3%, where the dotted line passing through the threshold point intersects the X-axis. Therefore, 12.3% of INTM is the minimum weight that is meaningful in the project ranking process.

It should be noted that, in the threshold analysis, weights of the other criteria are reduced from their original weights as the weight of INTM increases. These changes are due to the fact that, in AHP, the importance of a criterion is assessed not by absolute value but by relative weight in relation to other criteria. A change in the weight of a criterion causes the weights of other criteria to be changed. Hence, it is possible that a criterion that was meaningful before the adjustment can become insignificant afterward.

In addition, adopting a large number of criteria does not necessarily improve the accuracy of the analysis because of possible multicollinearities among criteria. Multicollinearity is said to exist when the factors in the rating system are highly correlated to each other. Multicollinearity is to be avoided because, if two factors are highly dependent on each other, they impose the same impacts on the dependent factors, or project rankings. Thus, the decision as to the ideal number of criteria should be based on the investigation of relationships among criteria, and should be made in such a way that criteria thought to be collinear are eliminated in the ranking process.

Revised INDOT Prioritization System

Based on findings through sensitivity analyses, this study recommends a Revised INDOT Prioritization System that overcomes weaknesses of the former system. This new system features:

- fewer criteria,
- elimination of possible multicollinearities among criteria, and
- addition of project "effectiveness" measures.

This system utilizes three broad categories of criteria:

- Needs,
- Effectiveness, and
- Impacts.

A number of *subcriteria* associated with each criterion is also be adopted. These subcriteria are used for developing the rating, or score, of the criteria with which they are associated. Determination of the proposed subcriteria was based on avoidance of multicollinearities. Table 5 shows the recommended criteria/subcriteria scheme.

Summary

The first part of this paper presented a new approach in prioritizing a number of highway projects for INDOT. The main feature of AHP is that it establishes a solid framework for assessing both quantitative and qualitative assets of alternatives. This framework allows the user to avoid any ambiguities in his/her judgments. Also, AHP is a straightforward procedure and easy to implement, without sacrificing quality of analysis.

In the second part of this paper, the significance of low-weighted criteria was investigated and the consequence of adopting too many criteria was pointed out. The Revised INDOT Prioritization System overcomes weaknesses of the former system.

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Table 1: Project-related data for 9 criteria

Project	Ac.Rate	V/C	Econ	Envr	Plan	Intm	Geo	Dvmt	MsLn
US30	0.041	0.323	3	2	1	1	0	3.337	0
SR3	0.408	1.144	3	2	1	1	0	2.260	0
I70	0.024	0.698	3	3	1	0	0	3.786	0
SR67	0.246	0.400	3	2	1	0	1	2.260	0
SR32	0.135	1.309	3	3	1	0	0	3.260	0
SR1	0.322	1.310	2	2	1	0	0	2.260	0
SR44	0.456	0.588	3	3	1	0	1	2.260	0
SR9	0.739	1.444	1	2	0	1	0	2.260	0
US35	0.753	1.246	3	3	1	1	0	3.337	0
I465_w	0.078	0.961	4	3	1	1	1	3.786	0
I465_us	0.026	0.744	2	3	1	1	0	3.786	1
US52	0.621	1.104	2	3	0	1	0	2.260	0
I69	0.143	0.968	1	2	0	0	0	3.786	0
SR37	0.410	1.046	2	3	0	0	0	2.260	0
I465_86	0.033	0.661	2	3	1	1	1	3.786	0
US231	0.688	0.362	3	2	1	2	1	3.260	1
SR2	0.101	1.132	3	3	0	0	1	2.439	0

Note: Ac.Rate: Number of accidents per 10,000 AADT
V/C: Volume/capacity ratio
Econ: Economic benefits or losses that will result from the project
Envr: Negative impacts to the environment
Plan: Do all the relevant plans agree that the project should be built?
Intm: Have all intermodal alternatives been addressed and considered?
Geo: Are the existing geometrics the reason for the project request?
Dvmt: The vision for the route in the future
MsLn: Does the project provide a vital missing link?

Table 2: Priorities of criteria

Criteria	Ac.Rate	V/C	Econ	Envr	Plan	Intm	Geo	Dvmt	MsLn	Total
Priority	.1512	.2326	.1046	.0930	.0930	.0465	.0930	.1046	.0814	1.0000

Table 3: Priorities for projects with respect to criteria

Project	Ac.rate	V/C	Econ	Envr	Plan	Intm	Geo	Dvmt	MsLn
US30	0.0079	0.0209	0.0698	0.0455	0.0690	0.0714	0.0435	0.0662	0.0526
SR3	0.0781	0.0741	0.0698	0.0455	0.0690	0.0714	0.0435	0.0449	0.0526
SR67	0.0471	0.0259	0.0698	0.0455	0.0690	0.0357	0.0870	0.0449	0.0526
SR32	0.0258	0.0848	0.0698	0.0682	0.0690	0.0357	0.0435	0.0647	0.0526
SR1	0.0616	0.0848	0.0465	0.0455	0.0690	0.0357	0.0435	0.0449	0.0526
SR44	0.0873	0.0381	0.0698	0.0682	0.0690	0.0357	0.0870	0.0449	0.0526
SR9	0.1415	0.0935	0.0233	0.0455	0.0345	0.0714	0.0435	0.0449	0.0526
US35	0.1441	0.0807	0.0698	0.0682	0.0690	0.0714	0.0435	0.0662	0.0526
US52	0.1189	0.0715	0.0465	0.0682	0.0345	0.0714	0.0435	0.0449	0.0526
I69	0.0274	0.0627	0.0233	0.0455	0.0345	0.0357	0.0435	0.0751	0.0526
SR37	0.0785	0.0678	0.0465	0.0682	0.0345	0.0357	0.0435	0.0449	0.0526
US231	0.1316	0.0235	0.0698	0.0455	0.0690	0.1429	0.0870	0.0647	0.1053
SR2	0.0193	0.0733	0.0698	0.0682	0.0345	0.0357	0.0870	0.0484	0.0526
I70	0.0046	0.0452	0.0698	0.0682	0.0690	0.0357	0.0435	0.0751	0.0526
I465_W	0.0149	0.0622	0.0930	0.0682	0.0690	0.0714	0.0870	0.0751	0.0526
I465_US	0.0049	0.0482	0.0465	0.0682	0.0690	0.0714	0.0435	0.0751	0.1053
I465_86	0.0064	0.0428	0.0465	0.0682	0.0690	0.0714	0.0870	0.0751	0.0526

Table 4: Ranking of projects

Project	Result	Rank	Old system	Project	Result	Rank	Old system
US35	0.0792	1	1	SR37	0.0567	10	14
US231	0.0734	2	2	SR2	0.0559	11	13
SR9	0.0694	3	7	I465_US	0.0534	12	6
US52	0.0654	4	10	I465_86	0.0521	13	11
SR3	0.0633	5	5	SR67	0.0498	14	15
I465_W	0.0628	6	3	I70	0.0491	15	12
SR44	0.0608	7	9	I69	0.0464	16	17
SR32	0.0604	8	4	US30	0.0426	17	16
SR1	0.0592	9	8				

Table 5: A recommended classification of criteria

Criteria	Subcriteria
NEEDS	(1) Equivalent Fatal Accident Rate
	(2) Volume/Capacity Ratio
	(3) Missing Link
	(4) Geometrics
	(5) Intermodal Alternatives
EFFECTIVENESS	(1) Net Present Value
	(2) Expected Change in High Volume/Capacity Ratio
	(3) Expected Change in High Accident Rate
IMPACTS	(1) Potential Economic Impacts
	(2) Environmental Impacts

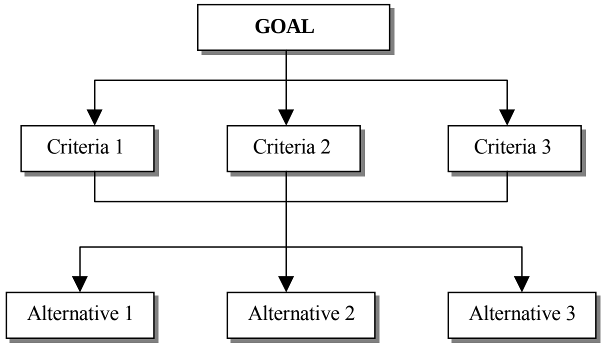

Figure 1: Structure of an AHP model

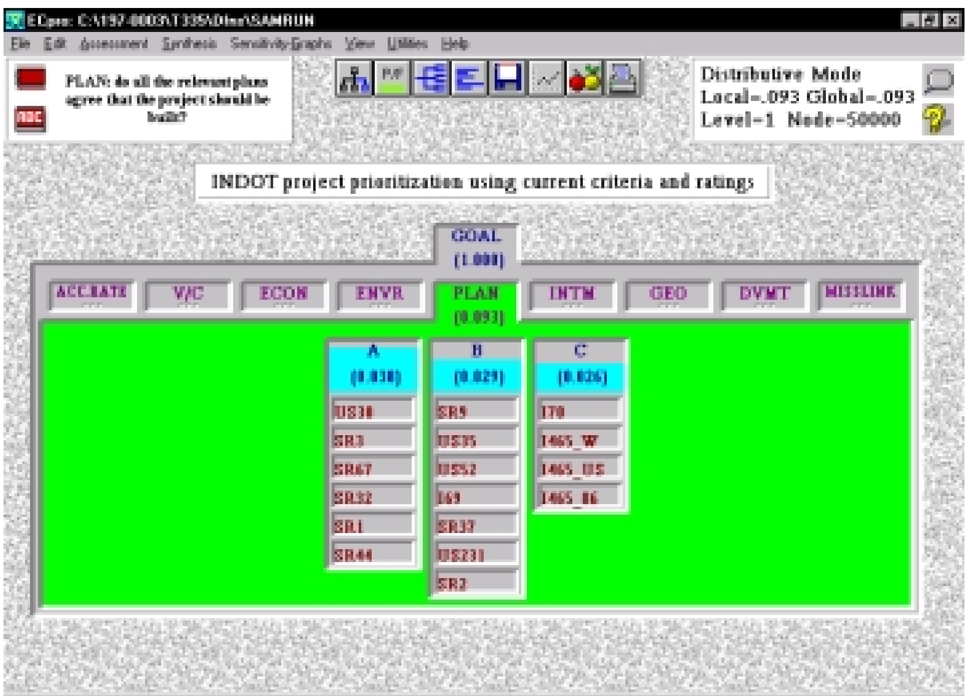

Figure 2: Main screen view of a hierarchical model

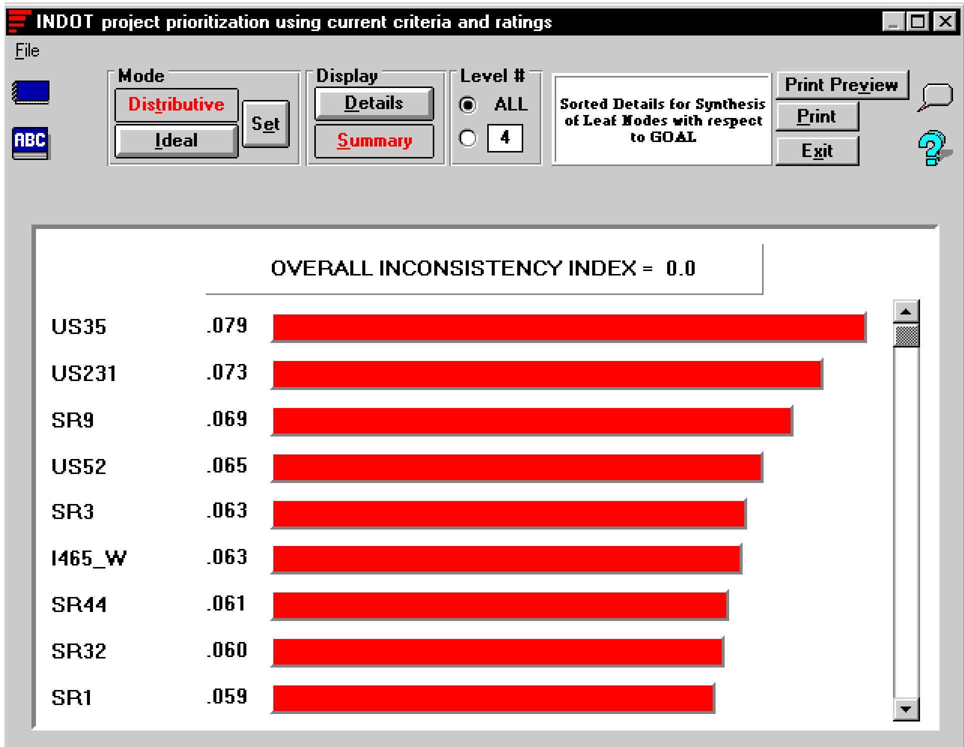

Figure 3: Final ranking of projects

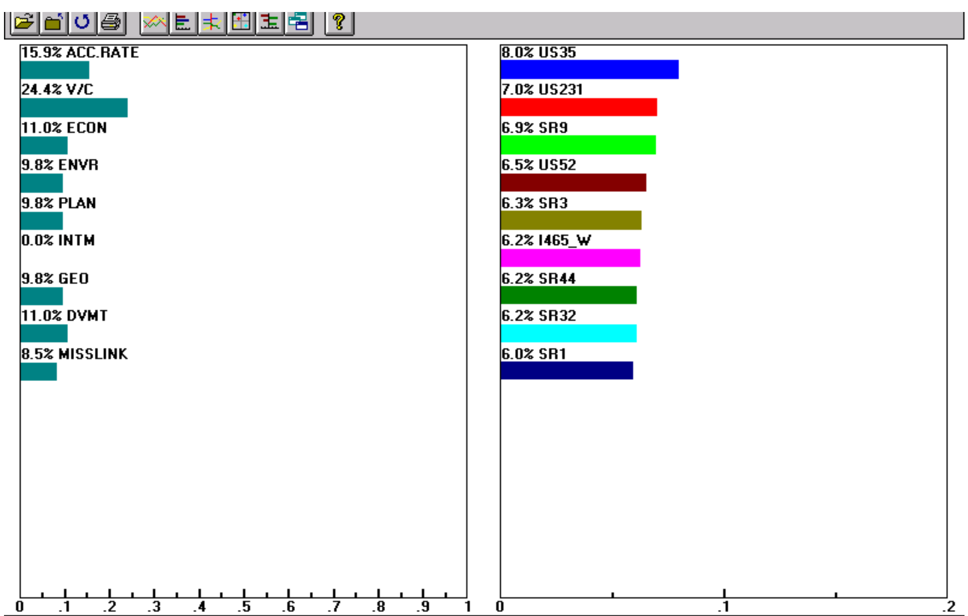

Figure 4: Current weights of criteria and project ranking

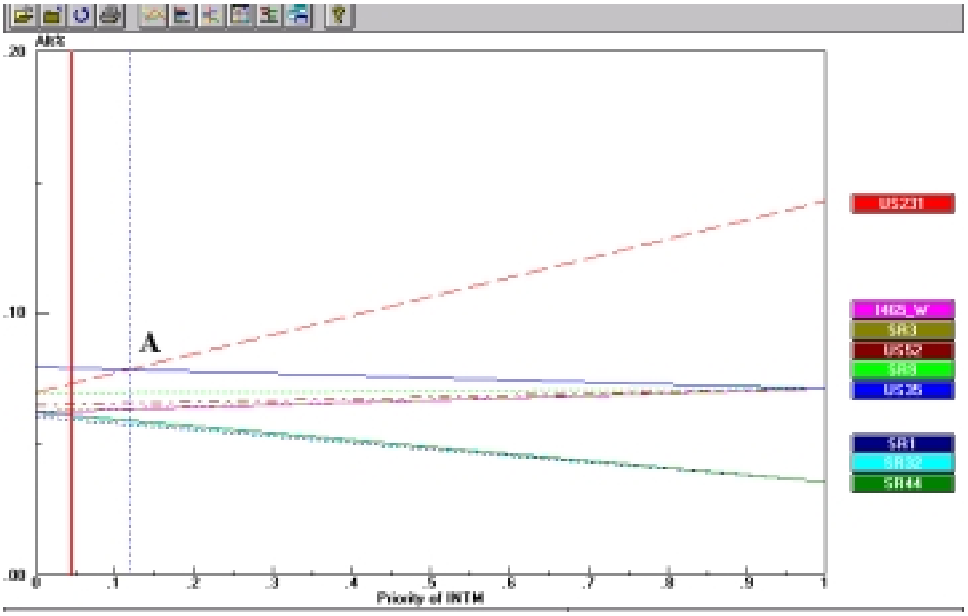

Figure 5: Threshold weight analysis for INTM

Multi-Use Trails: Is Everybody Happy?

Carol Buckley Lewis, *Central Transportation Planning Staff*

Abstract

Most off-road trails accommodate all non-motorized users, including bicyclists, joggers, pedestrians, skaters, and horses in some areas.

There are complaints from pedestrians about bicyclists and from bicyclists about pedestrians and from bicyclists and pedestrians about skaters.

This paper will address the characteristics of these users and why these characteristics may lead to conflicts. It will analyze counts of different types of users on trails and determine whether the perception of users fits reality, and if not, why not. The counts will be from the Minuteman Commuter Bicycle Path, a rail trail northwest of Boston, and the Dr. Paul Dudley White Bicycle Path, located along the Charles River in the inner metropolitan Boston area.

Finally, the possible solutions will be discussed, including width of trials, separation of users, and use of striping.

Technology-Based And Other Travel Demand Management Techniques For A Major Urban Campus

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Abstract

Travel Demand Management (TDM) for urban universities and other large institutions, a relatively recent program development effort, already is called a failure by many. Unrealistic goals, poor implementation strategies and inadequate measurement combine to create the sense of "no go" for TDM as a workable alleviator of traffic and parking congestion.

However, with parking construction costs escalating to $10-30,000/ space, loss of parking sites, related infrastructure expense, and continuing pressure to accommodate more autos, the implementation of TDM programs may be the only alternative.

This paper will identify and address issues related to the use of innovative solutions to developing effective TDM programs which reduce parking demand and minimize vehicular campus trips. A case study at the University of Wisconsin-Madison campus, population of 60,000, will be presented in addition to TDM studies conducted by the presenters at Michigan State University, Northwestern University and Georgia Institute of Technology. Low-tech and high-tech strategies that have been effective on these campuses will be discussed as well as those strategies that met with little support, compliance or interest from the campus population.

The approach of integrating advances in communications technology and intelligent transportation systems (ITS) can provide university and other transportation planners with cost-affordable solutions to meet the traffic and parking challenges. Ideas to be explored include:

- modems, rather than parking passes, for selected staff
- incentive/disincentive programs utilizing automated vehicle identification (AVI) systems or prepaid smart cards
- traffic and parking demand "calming" techniques such as flex-parking, "ad hoc" ride-sharing and U-PASS programs.

Guidelines for development, practice, implementation and policy-making will also be presented.

HOVShift: Modeling Time-Variant Mode Choice in the Seattle North Corridor

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Abstract

Regional forecasting tools are typically used to develop corridor-level mode shifts and static assignment High Occupancy Vehicle (HOV) population estimates. Recently, it is becoming increasingly recognized that traffic simulation models are needed to capture the dynamic intraperiod operational details of HOV facilities. The HOVShift model has been developed to provide a time-variant mode split component within a corridor-level traffic simulation context and link this component to an encompassing static regional mode split process. This allows the resultant operational characteristics and mode split to vary within the simulation period and at the same time remaining consistent with the regional aggregate forecast.

The approach of HOVShift is to employ a traffic simulation and a mode choice module iteratively. The traffic simulation generates estimates of HOV and non-HOV vehicle travel time for each origin, destination and time of trip start. The mode choice model then uses this information to produce an estimate of HOV population for each origin-destination-time triplet. When the modules are allowed to iterate to equilibrium under expected travel demand and network capacity, the resultant time-variant mode splits represent baseline or expected conditions. This approach allows for the identification of likely alternative mode usage by precise time-increments (here every 15 minutes) during an urban morning peak period.

The time-variant mode choice model within HOVShift is derived from the static Puget Sound Regional Council (PSRC) regional travel forecasting mode choice model. HOVShift uses a time-expanded logit approach that provides sensitivity to travel time and delay throughout the peak period. Model parameters insensitive to time (parking costs, for example) are preserved on an origin-destination basis consistent with the regional forecasting model.

In conjunction with a calibrated traffic simulation of the North Corridor network, the HOVShift framework is demonstrated to generate peak period High Occupancy Vehicle (HOV) vehicle populations that are consistent with the aggregated corridor forecasts from the PSRC forecasting model.

An Urban Transportation Planning Model for Shanghai - A City with Rapid Economic Growth and Urban Development

Eric Pengkuan Ho, *Gallop Corporation*; Ximing Lu, Junhao Li, and Meigen Xue, *Shanghai City Comprehensive Transportation Planning Institute*; and Richard H. Pratt

Abstract

Shanghai, a major commercial and industrial city in China, has experienced tremendous economic growth in the last decade. This has led to rapid and extensive development in the urban and transportation systems. Under such fast changing conditions, it is difficult to effectively model people's travel demand characteristics over an extended period of time. This paper presents an urban transportation planning model recently developed in Shanghai. The model consists of a number of model elements with relatively simple structures. Such a model framework allows us to calibrate and update the model easily so that it can accommodate any major changes in transportation services and travel demand characteristics. The model considers various kinds of variables that can effectively reflect the regional economic growth as well as the urban and transportation development in Shanghai.

The model is a sequential process consisting of trip generation, trip distribution, modal split and traffic assignment. A special feature of the model is a two-stage modal split process. The walk trips and personal motorized trips are determined before the trip distribution model. The rest of trips are split between bicycle and transit after the trip distribution model. The two-stage modal split process allows the model to separate different travel market segments with significantly different travel characteristics at the early stage of the modeling process. The model then handles the trips of various market segments with different model elements with appropriate model structures and variables.

The model was developed based on the data collected in the travel and traffic surveys in 1995. This paper first describes the model framework, then the structures of individual model elements. It will also discuss the calibration results of the model.

Introduction

Shanghai, a city with a population of more than 13 million, is a major commercial and industrial center in China. It is located at the mid-point of the East China Sea’s coastline, and near the outlet of the Yangtze River, the longest river and the most important inland waterway in China. The city, covering an area of 6,340 square kilometers, encompasses urban, suburban and rural areas.

Because of the economic reform, Shanghai experienced tremendous economic growth in the past decade. Numerous urban development projects were implemented. A number of major transportation projects were completed, such as the elevated Ring Road; bridges and tunnels; and the first subway line. Many more projects are being planed and will be implemented in the near future. The dynamic process of the urban development is expected to extend to the next decade.

Following the extensive urban and transportation development, the urban travel characteristics of the people in Shanghai have changed substantially. This is reflected in the traffic conditions of the roadway system and the changes in travel demand for various transportation modes. As development continues, the travel characteristics may change rapidly in the future. This creates a great challenge to transportation planning professionals to develop a travel demand model that can accommodate the fast changing conditions. Since the pace and the scale of the development have rarely been experienced in other cities around the world, the travel demand models applied to other cities may not be well suited for Shanghai.

In 1986, with the assistance of U.S. consultants, Shanghai developed the first contemporary travel demand model which was implemented in the EMME/2 transportation model software system(1). A number of travel and traffic surveys were conducted for the development of the model, which since then has been used for the planning and design of various transportation facilities.

Because of the dramatic economic growth and urban development, the model developed in 1986 was found to inadequately reflect the latest travel characteristics of the people in Shanghai. Also the model cannot take into account the new transit services. Therefore, in the early 1990s, the Shanghai government decided to conduct a second comprehensive transportation survey, and to revise the travel demand model. The second surveys were carried out in late 1995 and early 1996.

In order to develop a travel demand model suitable for the fast changing conditions in Shanghai, we need to investigate the changes in travel demand characteristics. In this paper, we first examine the urban development and its impacts on the people's travel demand, based on the data collected from 1986 and 1995 travel surveys, and the published statistics. We then summarize the major issues related to the development of the travel demand model, and present a travel demand modeling framework that can effectively accommodate the fast growing conditions in Shanghai. Finally, we discuss the development a multi-stage modal split process which is a specific feature of the modeling framework.

Demographic And Land Use Development

Economic Development

Shanghai has achieved tremendous economic development in the past several years. The Gross Domestic Product increased by more than 400 percent between 1985 and 1995. The economic structure also changed significantly. In 1985, the industrial GDP accounted for about 64 percent of the total GDP value. In 1995, the weight of the industrial GDP dropped to 57 percent, because of the rapid development in the service sector. Because of the economic growth, most of the people in Shanghai are much wealthier now than they were a decade ago. The average annual salary of an employee increased from 1,400 yuans[1] in 1985 to 9,300 yuans in 1995.

Demographic Growth

Because of the strict population policy, the resident population grew marginally between 1985 and 1995. In 1995, the resident population was about 13 million. However, due to the economic growth, a large number of people moved to Shanghai to seek employment. It was estimated that there were about 2.6 million non-residents in 1995. The majority of them were employed in industrials like construction and textile manufacturing and lived in temporary housing or dormitories provided by the employers. The socio-economic characteristics of these non-resident laborers are very different from those of the residents, who usually are regular state employees. On the other hand, the economic reform has also created a new class of high-income people who are businessmen, executives or managers of private or non-state enterprises.

Land Use Development

In the past decade, the land use patterns of Shanghai have changed enormously. Before 1985, major development in the city was confined to the region west of the Huangpu River. The center city was a very high density, mixed land use area with narrow streets. In the past ten years, major urban development has focused on the following four areas:

1. Development of the Pudong (East Huangpu) New Urban Area which, covering an area of about 250 square kilometers, will house 2 million people and provide 1.2 million employment opportunities;
2. Urbanization of the outlying rural area by expanding the urban area from 5,000 square kilometers in 1985 to more than 20,000 square kilometers in 1996;
3. Re-development of the center city area by replacing many old residential communities and factories with more than a thousand high rise residential and commercial buildings.
4. Development of several new satellite towns within 30-70 kilometers from the center city.

Transportation System Development

Motorized Vehicle Growth

Table 1 presents the growth of motorized vehicles from 1985 to 1995. Shanghai has adopted a relatively restrictive policy on owning and operating motorized vehicles, as compared with other cities in China(4). Still the number of passenger cars and motorcycles has grown very rapidly, almost four fold in ten years.

The number of taxis also grew dramatically, from 7,000 in 1985 to 37,000 in 1995. This has resulted in too many taxis with very low utilization rates in Shanghai. This has worsened the congestion situation and creates a parking problem on the streets. The growth of trucks was moderate during the same period, as compared with other kinds of motorized vehicles. This was due to the more efficient use of trucks.

[1] The current exchange rate is approximately 8 yuans per US dollar.

Highway System

The city of Shanghai was developed almost a century ago. The streets in the center city area, most of which were built before modern automotive technology was developed, are very narrow. Also, the roadway network was not developed in a systematic pattern. Many streets are circuitous. In the last decade, the city government has devoted a significant amount of effort to improving the highway network in following four areas:

1. Widening and upgrading the existing streets and constructing new streets to improve the connectivity of the street system in the center city;
2. Building a number of new radial arterials to accommodate the traffic generated from the newly developed areas.
3. Developing an elevated urban expressway system which consists of a ring road, a north-south expressway, and an east-west expressway; and
4. Building several bridges and tunnels crossing the Huangpu River to increase the number of traffic lanes crossing the Huangpu River from four in 1985 to eighteen in 1995.

Transit System

The development of the transit system between 1985 and 1995 lagged behind the development of the highway system. Until a few years ago, the only transit service in Shanghai was the "regular bus system" operated by the municipal bus company. During the ten-year period, there was moderate growth in the scale of the regular bus system, in terms of numbers of buses (from 4,700 to 7,500) and routes (from 300 to 520). However, the system ridership decreased significantly, from 13 million in 1986 to 9 million in 1995(6). The publicly operated bus service deteriorated due to a number of reasons. These include: 1) an aging bus fleet and insufficient system capacity; 2) extremely slow and unreliable schedules due to the congested roadway traffic; and 3) failing to adjust bus routes to accommodate the emerging transit markets in the new development areas.

Recently, the overall bus service has seen substantial improvements. There have been premium bus services introduced and operated by separate enterprises. These includes mini-bus service with flexible routes and stop locations, air-conditioned bus routes and express bus routes. The ridership of these services has increased significantly because they satisfy the increasing demands for high quality transit service. In 1992 there were about 110 routes of these premium bus services, accounting for less than one percent of total bus ridership. By 1995, the premium bus routes had increased to 420, and accounted for almost 15 percent of total ridership.

The first subway line in Shanghai, with a length of 16 kilometers and 13 stations, was opened in 1995. In the same year, the subway line carried about 240,000 passengers daily. The second subway line, with a length of 16.3 kilometers and 10 stations, is being constructed and is expected to open in 1999. The third line is in the design stage and is scheduled for construction soon.

Changes Of Travel Characteristics

Because of the economic growth and land development, there were significant changes in passenger travel characteristics between 1985 and 1995. The average per person daily trip rate increased from 1.79 in 1985 to 1.95 in 1995. The increase of the trip rate is less than expected, possibly due to the limited time available for the people to make additional trips. In China, most adults (both male and female) participate in the labor force. It limits the time available to make non-routine travel, such as trips for shopping or entertainment.

Table 2 shows the changes of major travel characteristics between 1986 and 1995. As shown in Table 2, the mode shares changed dramatically between 1986 and 1995. The shares of walk trips and bus trips dropped almost 10 percentage points. The share of bicycle trips increased from 31 percent to 45 percent. This reflects the fact that people were wealthier in 1995 than they were in 1985. In 1995, more people could afford to purchase bicycles and use them for their travel. Also, it indicates that in general people prefer riding a bicycle to taking the bus since riding a bicycle is usually faster and more reliable than riding the bus.

Table 2 also indicates the changes between 1986 and 1995 in average trip times, in minutes, of various travel modes. Except for passenger vehicles, the average trip times were much longer in 1995 than they were in 1985. This indicates that people had to travel further or at slower speeds in 1995 than in 1985.

Transportation Planning Modeling Issues

A critical concern in the development of travel demand models for Shanghai is how to handle the rapid and extensive growth in the urban and transportation systems. In such a fast changing environment, the reliability and predictability of a model that is calibrated based on the data collected at one point in time is more limited than under normal circumstances. In this section, we examine various issues which need to be considered in the development of transportation planning models in Shanghai. We categorize these issues into three different types.

Issues Related to Forecast and Policy Variables

1. Demographic and employment forecasts: There is no reliable information on the numbers of the non-resident population and non-state employees in the base year. Also, the amounts are very sensitive to economic conditions. It is thus extremely difficult to derive reliable estimates for these variables in the future.

2. Land Use development: The land use development will greatly affect the spatial distribution of various categories of employment and population. With such large scale development in Shanghai, it is difficult to forecast the spatial distribution of employment and population.

3. Transportation related policies: The travel demand on the transportation system will be greatly affected by the policies regarding motorized vehicle growth and land use development, e.g., the policy regarding the possession and operation of automobiles and

motorcycles. These policies should be clearly defined for developing reliable and meaningful travel demand.

Issues Related to Transportation Supply

1. New service patterns associated with the operation of the subway system: With the subway system implemented, the operations of various travel modes are no longer independent of each other. The bus route structure needs to be adjusted. The transfer activities between subway and other modes (e.g., bus, bicycle, walking, etc.) will become an important planning issue.

2. New travel patterns with the operation of subway system: With the operation of the subway system, people may make more non-commute trips. Also, people may make more trips with origins or destinations close to subway stations.

3. Emerging transportation modes or services: The service characteristics and fare structures of the emerging transit services are not stringently regulated currently. Also, their demands would be changed significantly once more subway lines are operated and the regular bus service is improved. Therefore, it is hard to represent these services in the transportation models and to project these services in the future.

Issues Related to Transportation Demand Behavior

1. More transportation choices: The people in Shanghai have experienced several new kinds of transportation services recently, such as subway, mini-bus, etc. People's behavior in response to these emerging services may not have reached a stable condition yet. The information collected recently may not be able to reflect people's behavior in the future.

2. Income effects and the trade-off between fare and service quality: With more transportation alternatives with different service characteristics and fare structures, the people in Shanghai now can choose among different alternatives based on the trade-off between cost and service quality.

3. Heterogeneous demand characteristics: The socioeconomic characteristics and travel demand characteristics of the people in Shanghai are more heterogeneous than ten years ago (e.g., resident population vs. non-resident population, state employees vs. non-state employees).

A New Modeling Framework

Modeling Principles

In order to deal with the specific modeling issues in Shanghai as discussed above, a new model framework had to be developed. We developed the framework based on a number of principals as stated below.

1. Modularization: The entire model set comprises a number of model elements. Each element can be calibrated or updated individually.
2. Sequential Structure: The model elements are executed sequentially to determine different planning variables. Such an approach can reduce the complexity of each model element.
3. Market Oriented: Different markets with little interaction, e.g., the walk trip market and the motorized trip market, are considered separately in the model framework.
4. Simple Structure: The structure of each model element is simple so that it can be updated, implemented and applied easily.
5. Policy Variables: The model framework allows certain policy variables, such as vehicle ownership, land use development, etc., to be directly and effectively considered in various model elements.
6. Multi-Modal Model: The model framework should reflect the interaction of various travel modes, and provide reliable and detailed information for the planning and design of various transportation facilities, such as transfer facilities at subway stations.

Model Flow

Considering the above principles, we developed a model framework that consists of a sequence of model elements with relatively simple structures so that the models can be calibrated, updated, implemented and applied easily. The sequential modeling process is considered the most practical modeling approach, in particular for the developing countries, where the availability of reliable data, software tools and professionals with advanced modeling knowledge is relatively limited.

The model flow is shown in Figure 1. After a traditional trip generation model, which estimates the zonal trip ends (i.e., productions and attractions), the Pre-Distribution Walk Trip Split Model (PWTSM) separates the zonal walk trip ends from the zonal total trip ends. Then the Pre-Distribution Personal Motorized Trip Split Model (PMTSM) separates the zonal motorized trip ends from the zonal total non-walk trip ends. The personal motorized trips include trips using automobiles, motorcycles, taxis and agency vehicles. Thus three kinds of trips are estimated on a trip end basis before the trip distribution procedure: walk trips, personal motorized trips and bike/transit trips.

These three types of trips represent three different travel markets with minimum interaction. Thus they can be considered separately. First, the walk trips are basically confined to short distance trips, e.g., intrazonal trips. Second, the personal motorized trips are usually made by the people with motorized vehicles available. Finally, the bike/transit market represents the majority of the travel made by the people. Bicycle and transit directly compete with each other. It is expected that the improvement of the transit system will primarily attract people who otherwise ride bicycles. It is thus necessary to consider these two modes together in the trip distribution and subsequent mode choice processes.

The personal motorized trips and bike/transit trips are then distributed independently with separate trip distribution models. It should be noted that the travel patterns of motorized trips and bike/transit trips are very different, in terms of socioeconomic characteristics of the travelers and trip length. It is thus appropriate to distribute these trips with different models.

Subsequently the Post-distribution Bike/Transit Trip Split Model separates the bike/transit trips into three different modes: bicycle, bus and rail. The model considers the service levels and the travel costs of these three competing modes. For the motorized person trips, they are further split into various vehicle types, such as motorcycle, automobile, agency van, etc., based on the projected growth of these vehicles and the area types of the trip origins and trip destinations.

The bike trip table, various motorized trip tables and truck trip tables are then assigned to the highway network, sequentially, using the equilibrium highway assignment procedure. The bus and rail trip tables are assigned to the bus network and the rail network separately. After the rail assignment, an access/egress mode split model is applied to determine, for each rail station, the access mode shares of the rail trips.

A special feature of this model framework is that the modal split procedure is broken down into three sub-models to be carried out separately before or after the trip distribution model. This "multi-stage" modal split procedure is believed to be more effective for dealing with the specific situation in Shanghai, as compared with the single pre-distribution or post-distribution modal split model. First, unlike the pre-distribution modal split model, which was adapted in the 1986 model framework(1), the multi-stage modal split procedure can effectively reflect the impacts of the development of the transportation system on modal split. Second, it handles three travel markets (i.e., walk, personal motorized, and bike/transit) in three sub-models separately, and allows policy variables (such as motorized vehicle growth, land use development, etc.) to be considered in individual sub-models directly. Third, the structures of individual sub-models are much simpler than a single modal split model (e.g. the post-distribution modal split model). These sub-models thus can be calibrated, implemented and updated easily. Fourth, it has greater flexibility for modal split procedure modification, if necessary, to handle any new travel modes. Finally, the multi-stage procedure allows us to conduct detailed demand analysis of individual travel modes. For example, the Post-Distribution Bike/Transit Model allows us to estimate a rail trip table, which can subsequently be used for detailed rail assignment and access modal split analysis.

Model Structure

Table 3 shows the structures of various model elements. As shown in the table, the model considers three types of variables which can effectively reflect the development in Shanghai:

1. Personal socioeconomic variables: These variables are related to economic development. It should be noted that vehicle availability can be affected by vehicle growth in the city and thus can also be considered to be a policy variable.
2. Land use and demographic variables: These types of variables can effectively reflect the amount and spatial distribution of land use development.
3. The transportation service and cost variables: These variables can be used to estimate people's travel behavior regarding the trade-off between service quality and cost of various transportation modes.

It should be noted that each model element considers only a few important variables. Also, the structures of most of the model elements are quite simple and widely used in travel demand models. With the data obtained from the 1995/96 survey, the various model elements were calibrated, validated, and implemented in the EMME/2 transportation planning model (7). Since the modal split procedure is the unique feature of this model framework, it is discussed in more detail in the next section.

Multi-Stage Modal Split Procedure

Pre-Distribution Walk Trip Split Model (PWTSM)

The PWTSM estimates the zonal walk trip ends as a percentage of the total trip ends derived from the trip generation model. Based on the 1995 survey data, we found that the percent of walk trip ends in the center city area is higher than that in the suburban area. There is strong mixed land use development in the center city area. It is thus believed that the percent of walk trips is largely dependent on the land use density and the degree of land use mix. We therefore consider the following variables in the model: population density, employment density and land use mix. The population density of a zone is the population divided by the area of that zone, while the employment density is the total number of employees divided by the area.

The land use mix reflects the balance between population and total employment within a zone. We consider a land use mix index *(mixidx)* similar to the entropy measure suggested by Kockelman(8) to represent the land use mix of a traffic analysis zone:

$$mixidx = -\frac{p\ln(p) + q\ln(q)}{\ln(2)},$$

where p is the ratio of population to the sum of population and "adjusted total employment", while q is the ratio of "adjusted total employment" to the sum. The "adjusted total employment" is the total employment adjusted by the regionwide "labor force participation ratio" (i.e., regional employment/regional population). The value of the index varies between one, when population and employment are perfectly mixed, and zero, when they are totally segregated.

It is important to consider the land use mix and land use density in the PWTSP. As mentioned before, a large amount of land in the outlying area is being developed in Shanghai. Present plans are for this newly developed area to have a lower density and relatively uniform land use pattern. As a result, the percent of walk trips for these areas can be expected to be much lower than that in the center city area. Based on the 1995 survey data, we found that the percent of walk trips is significantly correlated to the land use density and land use mix variables. We applied the regression analysis to estimate a set of non-linear equations with the following form for the PWTSP:

$$pwalk = \frac{a}{1 + b \bullet \exp(c \bullet mixidx + d \bullet empden + e \bullet popden)}$$

Table 4 shows the comparison of the observed and estimated percentages of walk trip ends for four major districts. As shown in the table, the estimation errors are within 10% in most cases. The performance of the model is particularly good in the center city area where most of the travel take place.

Pre-Distribution Personal Motorized Trip Split Model (PMTSM)

The PMTSM estimates the personal motorized trip ends of a traffic analysis zone as a percentage of the zonal total non-walk trip ends. Obviously, the people with motorized vehicles available are very likely to make trips with personal motorized vehicles. In addition to motorized vehicle availability, we also expect that the percent of personal motorized trips will be related to transit service. With more convenient transit service, e.g., an extensive subway network, people will be less likely to use personal motorized vehicles. With a transit service variable, the model can reflect the impact of the improved transit service on the use of motorized vehicles.

We define two zonal transit accessibility indices for this model, one for the production end and the other one for the attraction end. The transit accessibility of a zone at the production end is defined as the percentage of the regionwide employment which is accessible within 90 minutes of travel time from that zone. Similarly, the transit accessibility of a zone at the attraction end is the percentage of regionwide population that can arrive at that zone within 90 minutes of travel time. These indices can easily be derived from the transit network. We chose the value of 90 minutes among several values tested based on correlation analysis. We considered the following non-linear equation for the PMTSM:

$$pmotor = a \bullet \exp(b \bullet accidx)$$

The comparison of observed and estimated numbers of motorized trip ends by district is shown in Table 5, which indicates that in most cases, the percents of estimation errors are less than 10%. In general, the model performs quite reasonably in the center city area and the outer city area. However, it performs poorly in the new development area, where special adjustment procedures may need to be developed.

Post-Distribution Bike/Transit Mode Split Model (PBTSM)

The PBTSM is a Multi-Nominal Logit Model, which splits person trips into three modes: bicycle, bus and subway. It should be noted that subway is a new and modern mode in Shanghai. We calibrated the model using disaggregate trip records obtained from the 1995 home interview survey. We considered the following variables in the model:

- In-vehicle time (for bus and subway)
- Out-of-vehicle time (for bus and subway)
- Transit fare (for bus and subway)
- Bicycle time

The calibration results are shown in Table 6. The calibrated coefficients are quite reasonable considering the following aspects:

1. The coefficient of the out-of-vehicle time is almost two times of that of in-vehicle time for Home Based Work trips. This relationship is similar to that we usually find in the U.S.
2. The ratio of the out-of-vehicle time coefficient to the in-vehicle time coefficient for Home Based Work trips is larger than the ratio for Non-Home Based Work trips. Again, this relationship is similar to that usually found in the U.S.
3. The transit fare coefficient is about one-tenth of the in-vehicle time coefficient. It implies that the value of time is about 6 yuans per hour, roughly equal to the average hourly wage of people in Shanghai in 1995.
4. The subway constant is greater than the bus constant (considering the negative sign). It implies that subway is regarded more favorably than bus if their weighted travel times and fares are the same.
5. The bicycle constant (set to zero in the model) is larger that the bus constant and the subway constant, indicating bicycle is regarded more favorably than transit modes for trips which are short enough that the higher time coefficient does not counterbalance the effect of the constant.

With the calibrated coefficients, we applied the model with the 1995 observed trip tables and then compared the estimated regional mode shares with the observed mode shares. As shown in Table 10, the observed and estimated mode shares are not significantly different. We then adjusted the modal constants based on the differences in the observed and estimated mode shares. The finally adjusted modal constants are shown in Table 10. The ordinal relationships among the finally adjusted modal constants are basically the same as those among the calibrated constants.

Conclusions

The economic growth in Shanghai during the last ten years is astonishing. This has led to rapid and extensive urban development in Shanghai. Under such fast changing conditions, it is difficult to develop a model that can effectively represent people’s travel demand characteristics over an extended period of time.

Based on study of the urban development in the last decade and its impacts on travel characteristics, we can summarize a number of modeling issues specific to the rapidly changing environment in Shanghai. These include the following three aspects:

1) the reliability of major forecast variables, such as population, employment and vehicle availability, etc., in both model calibration and model applications;
2) the way to represent the emerging transportation services in the transportation planning models and the projection of such services into the future;
3) the stability and heterogeneity of the people's travel demand characteristics under the rapidly changing environment.

This paper presented a travel demand modeling framework which consists of a number of model elements with relatively simple structures. Such a framework allows us to calibrate and update the model easily so that it can accommodate any major changes in transportation services and travel demand characteristics. It is a sequential modeling process, consisting of trip generation, pre-distribution modal split, trip distribution, post-distribution modal split, and traffic assignment procedures. Such a model framework allows us to effectively represent various transportation service variables, transportation policy variables, land use development variables and socio-economic variables in individual model elements. Also, the multi-stage structure increases flexibility for developing detailed analysis procedures of individual travel modes, such as rail assignment and access modal split procedures.

A special feature of the framework is a multi-stage modal split procedure, which consists of the PWTSM, the PMTSM and the PBTSM. This procedure is believed to be more effective, as compared to the traditional modal split models, for reflecting the impacts on mode shares of Shanghai's socio-economic development, motorized vehicle policy and growth, land use development and transportation system development. We calibrated these models using the 1995 survey data. The calibrated model structures and coefficient values are quite reasonable. Also, the validation results indicate that these models can replicate the 1995 mode shares quite well. It demonstrates that the new modeling framework is applicable and is an effective approach for dealing with the specific development conditions in Shanghai.

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Table 1: Growth of Motorized Vehicles From 1986 to 1995

	1986	1992		1995	
	Value	Value	% Growth From 1986	Value	% Growth From 1986
Passenger Cars	35,000	78,700	124.9	169,400	384.0
Trucks	61,200	90,800	48.4	119,300	94.9
Motorcycles	19,500	56,800	191.3	89,100	356.9
Total	115,700	226,300	95.6	377,800	226.5

Source: (3)

Table 2: Changes of Mode Shares and Average Trip Lengths Between 1986 and 1995

	1986	1995
Mode Shares (Percent)		
Walk	41.3	32.8
Bicycle	31.3	45.1
Transit	24.1	15.1
Automobile/Motorcycle	3.3	7.0
All Modes	100.0	100.0
Average Trip Lengths by Mode (minutes)		
Walk	13	19
Bicycle	21	35
Bus/Subway	48	62
Passenger Vehicle	55	55
All	33	36

Source: (3)

Table 3: Types and Variables Used in Various Model Elements

Model Element	Model Type	Variable Used											
		Personal Socio-Economic				Land Use & Demographic					Service & Cost		
		Age	Income	Occupation	Vehicle Availability	Population	Employment	Area Type	Land Use Density	Land Use Mix	Transit Accessibility	Travel Time	Travel Cost
Truck Trip Generation	Regression					X	X	X					
Truck Trip Distribution	Gravity											X	
Person Trip Production	Cross Classification	X	X	X	X			X					
Person Trip Attraction	Regression					X	X	X					
Pre-Distribution Walk Trip Split	Regression							X	X	X			
Pre-Distribution Motorized Trip Split	Regression				X			X			X		
Motorized Trip Distribution	Gravity							X				X	
Bike/Transit Trip Distribution	Gravity							X				X	
Motorized Sub-mode Split	Cross Classification				X			X					
Bike/Transit Mode Split	Logit							X				X	X
Rail Trip Assignment	Multipath(1)											X	
Bus Trip Assignment	Multipath(1)											X	
Highway Assignment	Seq. Cap. Constrd.(2)											X	
Rail Access/Egress Mode Split	Logit								X			X	

(1): Multipath tranist assignment procedure provided by EMME/2

(2): Equilibrium Auto assignment procedure with various types of vehicles loaded to the network sequentially

Table 4: Comparison of Observed and Estimated Walk Trip Ends by Area

	Trip Production			Trip Attraction		
	Observed	Estimated	% Error	Observed	Estimated	% Error
Home Based Work						
Center City Area	459,200	415,300	-9.56	466,900	460,300	-1.42
Outer City Area	189,600	197,600	4.22	182,000	168,600	-7.34
New Development Area	184,400	159,600	-13.45	190,000	161,600	-14.95
Rural Area	923,000	870,100	-5.73	917,200	854,100	-6.87
Overall	1,756,200	1,642,600	-6.47	1,756,200	1,644,800	-6.34
Home Based School						
Center City Area	998,800	1,023,700	2.49	995,500	1,055,000	5.98
Outer City Area	408,000	375,000	-8.09	411,100	356,300	-13.33
New Development Area	336,200	312,700	-6.99	343,600	316,000	-8.02
Rural Area	688,700	671,700	-2.47	681,200	667,500	-2.01
Overall	2,431,700	2,383,100	-2.00	2,431,700	2,395,000	-1.51
Home Based Other						
Center City Area	1,125,800	1,139,500	1.22	1,132,400	1,171,600	3.46
Outer City Area	319,700	297,300	-7.01	311,700	284,200	-8.83
New Development Area	273,500	250,100	-8.56	278,300	266,300	-4.31
Rural Area	542,400	536,200	-1.14	538,600	567,500	5.37
Overall	2,261,300	2,223,100	-1.69	2,261,300	2,289,700	1.26
Non-Home Based						
Center City Area	159,900	152,000	-4.94	159,900	151,800	-5.12
Outer City Area	39,600	34,800	-12.12	39,700	35,700	-10.05
New Development Area	37,200	30,300	-18.55	37,500	31,300	-16.49
Rural Area	78,800	68,400	-13.20	78,200	71,100	-9.07
Overall	315,500	285,400	-9.54	315,500	290,100	-8.05

Table 5: Comparison of Observed and Estimated Personal Motorized Trip Ends by Area

	Trip Production*			Trip Attraction		
	Observed	Estimated	% Error	Observed	Estimated	% Error
Home Based Work						
Center City Area	176,000	159,400	-9.43	164,200	150,800	-8.16
Outer City Area	122,800	124,600	1.47	110,400	106,700	-3.35
New Development Area	108,900	113,800	4.50	200,800	143,800	-28.39
Rural Area	325,400	332,100	2.06	367,200	377,100	2.70
Overall	570,300	563,900	-1.12	842,500	778,500	-7.60
Home Based Other						
Center City Area	64,800	61,200	-5.56	73,400	68,900	-6.13
Outer City Area	32,500	36,000	10.77	33,200	32,800	-1.20
New Development Area	23,700	38,400	62.03	30,300	42,900	41.58
Rural Area	130,000	131,800	1.38	137,900	145,400	5.44
Overall	186,000	201,500	8.33	274,900	290,000	5.51
Non-Home Based						
Center City Area	69,200	63,500	-8.24	79,800	74,700	-6.39
Outer City Area	38,400	30,800	-19.79	42,500	34,700	-18.35
New Development Area	32,600	30,100	-7.67	38,100	35,000	-8.14
Rural Area	89,600	99,800	11.38	102,300	106,200	3.81
Overall	185,000	174,200	-5.84	262,700	250,600	-4.61

* For persons with no motorized vehicle available

Table 6: Calibration Results of the Post-Distribution Bike/Transit Split Model

Variable	Mode Applied	HB Work	Non-HB Work
In-Vehicle Time (min.)	Bus, Rail	-0.0387 *(-3.5)**	-0.0346 *(-3.8)*
Out-of-Vehicle Time (min.)	Bus, Rail	-0.0798 *(-7.9)*	-0.0484 *(-5.9)*
Bike Time (min.)	Bike	-0.0749 *(-8.7)*	-0.0706 *(-10.5)*
Transit Fare (10^{-2} yuans)	Bus, Rail	-0.00396 *(-2.3)*	-0.00412 *(-10.5)*
Bus Constant	Bus	-2.595	-2.322
Rail Constant	Rail	-1.279	-2.364
Rho^2		0.2558	0.2095

* *(xx.xx)*: t-value

Table 7: Adjustment of Modal Constants of the Post-Distribution Bike/Transit Split Model

	Home Based Work			Non-Home Based Work		
	Bike	Bus	Rail	Bike	Bus	Rail
Observed Mode Share	0.715	0.277	0.008	0.718	0.271	0.011
Estimated Mode Share	0.862	0.127	0.011	0.752	0.240	0.008
Calibrated Modal Const.	0.000	-2.595	-1.279	0.000	-2.322	-2.364
Adjusted Modal Const.	0.000	-1.334	-1.321	0.000	-1.789	-1.463

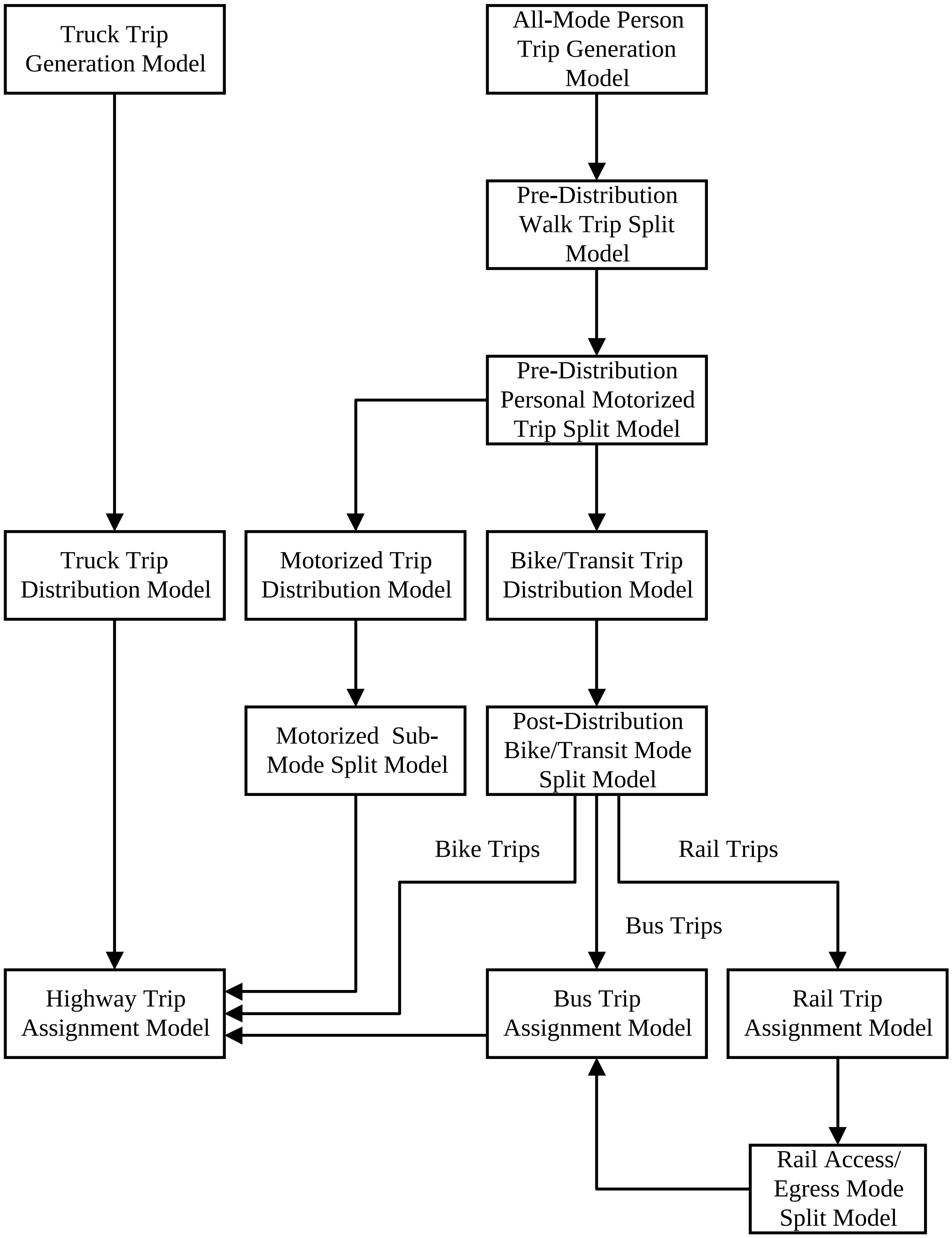

Figure 1 Model Framework

A Short-Term Forecasting Model Of Transit Demand And Service

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Abstract

Urban transportation modeling procedures have traditionally been applied to long-term forecasting of highway traffic volumes. As a result, during the past decade, the transit industry has been keenly interested in analytical tools that would be suitable for short-term transit planning applications. In Florida, for example, these applications include five-year forecasting of transit demand for Transit Development Plans, route-level analysis, scenario testing, and service simulation.

In response to this need, the Florida Department of Transportation funded a research project to develop a short-term transit forecasting model. Operating at the level of individual routes, the model explicitly addresses the two-way interactive relationship between transit demand and service provision. This is important for two reasons. First, unlike roadway supply, transit supply may be changed (in response to demand) in relatively short time-frames. Then, not only is transit demand a function of supply, but supply is also a function of demand. Second, there may be several different transit service configurations that can meet the transit needs of an urban area. A critical question is: which configuration is most cost-effective? A tool that iteratively modifies transit service attributes in response to demand patterns is needed to answer this question.

This paper presents an operational model for short-term forecasting of transit demand and supply characteristics. The model is similar to that developed by Peng, et. al. (*Transportation* **24(2)**, 1997) in that it incorporates a system of equations aimed at modeling transit supply, demand, and inter-route relationships in an integrated framework. The model is intended to serve as a short-term planning and simulation tool for transit systems. The model system is formulated as a simultaneous equation system where ridership and service attributes are determined at the route level in an iterative framework. In addition, a set of parameters are included so that performance measures may be computed at each iteration of the model. These measures include operating expense per vehicle revenue mile and hour, operating expense per passenger mile, passenger trips per vehicle revenue mile, revenue per passenger trip, and farebox recovery ratio. These statistics provide a measure of the effectiveness of the transit service configuration at each iteration. The model system is integrated with a GIS tool so as provide a visually powerful database environment for analysis and display of results. The model system has been run and tested using transit network and demographic data from the Volusia County area in Florida. The presentation will offer an overview of the model system and show how it can be used in practice for transit service simulation and analysis at the individual route-level.

The Addition Of A Toll Nest To Regional Mode Choice Models

Shohreh Shoaee, *Orange County Transportation Authority*; Andy Mullins, *Houston-Galveston Area Council*; Dawn L. McKinstry, Phillip Reeder, and William A. Davidson, *Parsons Brinckerhoff Quade & Douglas, Inc.*

Abstract

The general purpose of Major Investment Studies (MIS) is to assess the full range of transportation strategies and identify a preferred solution to address existing and future deficiencies in a corridor. The preferred solution should address capacity requirements and mobility needs and should be sensitive to environmental concerns and other problems associated with growing traffic congestion . An increasingly important and popular alternative revolves around congestion pricing strategies -- specifically toll road and/or high-occupancy toll road facilities.

The Major Investment Study process provides a systematic approach to identify and assess a full range of transportation alternatives. One of the major tools needed in assessing alternatives is a travel demand forecast that represents best practice, particularly in the area of mode choice. The results of the travel forecasting effort are used in many facets of the MIS process. For the travel forecasting effort to be used to the greatest benefit, however, it needs to specifically address all the modes that may be considered in the future.

For two recent major investment studies in different parts of the county, the regional travel demand models were expanded to include a toll nest in the mode choice models. In both Houston, Texas, and Orange County, California the models were enhanced to reflect the choice between toll and non-toll road paths; both metropolitan areas utilize nested logit mode choice models. Placement of this choice within the mode choice model structure, rather than simply in the assignment procedure, allows this path choice to consider the full range of behavioral trade-offs among these route-based alternatives.

This paper will examine how the toll/non-toll nest was added to the existing mode choice models, what tests were made, and the results for each of the two areas. In the case of Houston, model forecasts were compared (in the base year) against actual traffic counts. In Orange County, the model results were compared with previously estimated volumes based upon non-traditional travel model techniques.

The paper will provide useful information to agencies and urban areas desiring to implement a methodological approach for estimating the impact of new or additional toll road facilities.

An Integrated Disaggregate Model System for Intercity Travel Demand Forecasting

Kimon Proussaloglou and Kevin Tierney, *Cambridge Systematics, Inc*.

Abstract

This paper describes the estimation and application of an integrated modeling framework to develop forecasts of diverted and generated intercity travel in response to the introduction of new or greatly improved transportation services or facilities. The estimates of diverted travel that are produced reflect the trips that would be made by a different travel mode or by another route if the proposed investment was not made. The estimates of generated trips correspond to the latent demand and reflect the amount of intercity travel that is expected only if the proposed transportation investment is made.

The integrated model system consists of a set of multinomial and/or nested logit choice models that reflect travelers' interrelated decisions. The individual models address trip generation, trip distribution, mode choice, and route selection from an individual traveler's perspective. Data collection and model estimation are based on individual traveler surveys. Respondents' intercity travel patterns are analyzed to assess the relative importance of the factors affecting the number of intercity trips taken by each traveler, their choice of destination, and their mode and route choice behavior.

The modeling framework discussed in this paper presents an improvement over the traditional approach that treats travelers' decisions as separate sequential stand-alone models of trip generation, trip distribution, mode split, and assignment models. The nested structure of the integrated model system connects all model components by passing information from one choice stage to the other during both model estimation and application. A set of inclusive value (logsum) terms is used to lin the various components of the model system within a structure that reflects travelers' interrelated decisions. The fully disaggregate model system provides for an internally consistent set of individual model components with changes in the level of service having an impact on all aspects of travelers' choice behavior.

To illustrate the modeling framework, we describe its application to two intercity demand analyses: the development of passenger forecasts for the Italian High Speed Rail System and the proposed Buenos Aires-Colonia Bridge between Argentina and Uruguay. A sample enumeration method is used to produce forecasts of individual choice probabilities and trip making patterns in a manner that is consistent with the disaggregate model estimation. A customized user-friendly application interface is developed to support a database structure that maintains level of service information for the entire study area. The model application outputs include a range of tables and figures summarizing the projected origin-destination travel by each available mode.

Survey of Users on the Norwottuck Rail Trail, Massachusetts

Jeffrey McCollough, *Pioneer Valley Planning Commission*

Abstract

In recent years, much research has been published in the transportation planning arena regarding the characteristics of the bicycling and walking public. Documentation of these modes provides local and regional planners with valuable data for justifying large investments of both time and money in improved facilities for bicycling and walking. However, one shortcoming for data from national studies is a perception that national data is too far removed from local conditions to be of value. A study of usage of a bikepath in Davis, California, or Durango, Colorado is often viewed with skepticism. The "numbers from somewhere else don't work here" mentality usually prevails at the local level.

Under ISTEA, the Pioneer Valley Region began a long term investment program in bicycling and walking facilities. In 1993 a study of the Pioneer Valley Region's most popular bikepath; the Norwottuck Rail Trail with the goal of providing local communities with local statistics on who uses a bikepath. The Norwottuck Rail Trail is multi-use, 8-feet wide, asphalt path, extending 10 miles from the west bank of the Connecticut River in Northampton, eastward to Amherst. The area is home to five colleges, with a combined enrollment of 30,000 students and a large population of bicyclists and pedestrians.

The methodology for the survey was straight-forward: Randomly stop and ask questions of as many people as possible and keep track the number of people not surveyed. Data was collected from dusk to dawn on a weekday and again over the weekend. Eight survey questions were asked in an interview format including: trip origin, trip destination, travel mode to the path, trip purpose, and frequency of use. Three staffed survey stations were strategically located along the path and users were enticed into stopping with free refreshments and a persistent staff. Every user interviewed was rewarded with a discount coupon at a bikepath restaurant.

The goal was to define the Bikepath user with data that could be put to use in planning and designing future facilities. Information on where people came from and how frequently they used the path provides local and regional planners with strong "regional" data to analyze future corridors for both recreational and transportation use. For example; Trip purpose inquiries revealed that the majority of weekend travelers used the trail for recreation yet one in four weekday trips would have been made by car if it weren't for the trail. The survey also found that senior citizens comprised a much larger portion of users than previously thought and that recreational users were willing to travel more than an hour by car to reach the trail. This information is useful when locating and estimating parking demand for a new facility.

User surveys can be a valuable planning tool for predicting potential use and identifying the catchment area as well as parking requirements for new facilities. Understanding how bicycle and pedestrian traffic moves in platoons just like vehicle traffic is useful in coordinating signalized crossings and selecting a design width. Finally relying on local data decreases the chance for error and greatly improves the credibility of regional planning efforts.

Bringing It All Together: Meshing Higher Densities, Transit Facilities, and Traffic Calming in Older Neighborhood Business Districts

Daniel Meyers, AICP and Bob Kost, ASLA, *BRW, Inc.*

Abstract

In metropolitan areas nationwide, the majority of older neighborhood business districts have been bypassed in favor of more auto-oriented suburban commercial districts. These areas were typically developed 50 to 75 years ago with a limited range of uses, often with single-family neighborhoods surrounding a small, streetcar or commuter rail oriented business node. In many cases, especially in the Twin Cities, the role of transit has diminished steadily and automobile dependency has increased since that time. Additionally, the importance of these areas has diminished accordingly. Yet a minority of these neighborhoods have thrived by becoming more "urban", expanding and diversifying their mix of uses and customer base. To what extent can this approach be used to revitalize or strengthen other such neighborhood business districts?

The session will examine the Linden Hills neighborhood of Minneapolis. The Linden Hills neighborhood has a successful "downtown", oriented toward neighborhood retail and specialty retail. Through a neighborhood initiated planning process, residents are attempting to retrofit a peripheral, more auto-oriented district, making it more urban in character and more balanced between commercial and residential land uses, through a series of urban design and traffic engineering guidelines and policies. Traffic issues have become more important as downtown Linden Hills attracts more neighborhood and sub-regional trips to the area. Maintaining efficient traffic flow and providing ample parking while preserving the historic and small neighborhood atmosphere of Linden Hills, have become major goals during the participation process. At the same time, local business interests feel threatened by an active neighborhood association, and fear being forced to change their longstanding approach and orientation.

The session will present the techniques used during the planning process on how streets were viewed as complex community settings that serve a variety of functions. That not only do streets move traffic but are also environments used for walking, bicycling, jogging, and socializing. The design criteria supported a number of uses for streets including street humps, special paving, street furniture, and integrated planting areas. Additionally, a goal of the plan was for the design and management of the street space for the safety and comfort of the residents. That rather than focusing only on the needs of autos, streets should be designed with the needs of pedestrians, bicyclists, transit riders, and joggers. It was viewed by neighborhood residents that efficient traffic movement should be allowed but that the plan should not facilitate it. It was a goal of the plan that the street should provide access to all dwellings in an efficient way and that access to shops, schools, and parks should be convenient. Finally, the traffic control measures recommended to be used in Linden Hills will be explained, these included: narrowing traffic lanes, elimination of curbed sidewalks, change of paving materials at intersections and crosswalks, speed bumps and humps, traffic circles, and extensive landscaping.

This session examines the introduction of new urbanist concepts such as mixed use development, introduction of higher densities, and an orientation toward traffic calming and transit, into established older neighborhood business districts and suburban downtowns. This paper focuses on one case study: an attempt to introduce mixed use, transit and pedestrian oriented design, traffic calming, higher densities and shared parking into one Minneapolis neighborhood through a locally-initiated planning process. It illustrates the benefits and some of the pitfalls of revitalizing these areas by trying to make them more **urban,** rather than second-rate imitations of the auto-oriented suburb.

The Problem

In metropolitan areas nationwide, the majority of older neighborhood business districts have been bypassed in favor of more auto-oriented suburban commercial districts. These areas were typically developed 50 to 75 years ago with a limited range of uses, often as streetcar or commuter rail-oriented nodes or corridors surrounded by largely single-family neighborhoods. In many urban areas, and nowhere more so than in Minnesota's Twin Cities, the role of transit has diminished steadily since that time. The importance of these business districts has diminished accordingly as commerce moved out beyond them, following homebuyers to the suburbs where new strip centers could be built with ample parking.

Since that time, efforts at revitalizing neighborhood business districts have frequently focused on making them more "suburban" by adding surface parking lots and replacing traditional storefront buildings with big box retail. The success of these efforts has been questionable, since a suburban-style retrofit is likely to result in removal of the small buildings and sidewalk orientation that give these districts their appeal. However, some neighborhood business districts are now trying a new approach: becoming more "urban" by increasing their density, diversifying their mix of uses and expanding their customer base.

There have been several neighborhoods in Minneapolis that have attempted to implement a planning approach to maintaining higher densities and providing efficient transportation in older areas. This session examines a middle-class neighborhood in southwest Minneapolis in the Twin Cities that is trying variations on this approach: the Linden Hills neighborhood of Minneapolis.

Linden Hills: Coping with Success

Linden Hills, unlike most city neighborhoods, contains most of the components of a free-standing town. Close to the city's southwest corner, it is somewhat isolated from the rest of the city by two lakes and surrounding parkland to the north and east. With a population of around 7,000, it contains a full complement of parks, schools and civic buildings, a wide range of housing types, and enough commercial development to satisfy both daily needs and specialty shopping. In fact, Linden Hills contains no less than three commercial districts, known by their primary intersections:

- *43rd Street and Upton Avenue:*
  The neighborhood's "downtown," a lively mix of small unique shops, restaurants and offices surrounded by a mixture of multifamily and single-family housing. Only a few blocks from the Lake Harriet Parkway, it attracts substantial pedestrian traffic. However, many shoppers and strollers arrive by car, and traffic congestion can be a problem, one that is made worse by the fragmenting of off-street parking into many small lots, most reserved by specific businesses.

- *44th Street and Beard Avenue:*
  This district is a corridor that extends for several blocks; it originally developed around an old streetcar line that parallels 44th Street. Today it contains a varied, if discontinuous, mix of small commercial and office uses ranging from automotive repair to specialty garden supplies, interspersed with open space and parking lots. Buildings are generally one story in height; sidewalks are discontinuous and landscaping is minimal. Shared parking is available in a lot leased by businesses from the city. A small park, undeveloped except for a grove of trees, provides green space.

- *44th Street and France Avenue:*
  This district plays the role of "edge city" to 43rd and Upton's "downtown." It contains a number of larger businesses such as a supermarket, garden center, gas station and liquor store, all developed in a suburban manner -flat-roofed one-story buildings, separated from the street by large expanses of parking. Smaller two-story buildings also exist, many of them just across France Avenue, the city boundary. While most people find the district unattractive, it meets many of their daily shopping needs and is served by two bus routes.

All three districts are linked by 44th Street, a minor arterial with two lanes of traffic, lined by a mixture of multifamily and single-family housing, as well as several churches and private schools. It is a bus route, and also receives heavy bicycle use in the warmer months, since it connects the lake parkway system to several neighborhoods.

Unlike many urban neighborhoods, Linden Hills suffers relatively little from housing deterioration or commercial vacancies. Its reputation is that of a highly desirable neighborhood in which to live or do business. The challenges facing the neighborhood are largely the product of its own success. The tension between commercial viability and residential livability is manifest in many ways, the most noticeable of which is traffic *and parking congestion.* Businesses are dependent on a larger market area than the neighborhood alone, and as they draw shoppers from this larger area, residents notice more traffic and a shortage of parking. A related trend is the *increase in specialty retail shops and restaurants* which depend on this larger market and some of which have replaced neighborhood service businesses.

The Neighborhood Revitalization Program and the Planning Process

Neighborhood planning in Linden Hills, as in all of Minneapolis' 81 neighborhoods, has been spurred in the 1990s by the Neighborhood Revitalization Program (NRP), a citywide program that works to build neighborhood capacity through organizing, planning, and allocating funding for improvements. Because each neighborhood is given its own "pot of money" to allocate to projects that it has identified, there is a tremendous incentive to undertake the often exhaustive and time-consuming planning process. NRP has been criticized, however, for its lack of connection with the city's own planning department and with a citywide plan (the city's recently completed comprehensive plan was undertaken after most neighborhood plans were complete).

Linden Hills' NRP process began in 1994 with the creation of a number of task forces, including one that focused on the commercial districts. It was largely a resident-driven process, with little input by the business community. The task force saw increasing pressure for more intensive and traffic-generating commercial development, especially in the 43rd and Upton district. During this period, proposals for a coffee shop and a bicycle rental business in that area were defeated, based largely on their lack of off-street parking, while a barbecue restaurant took over a former gas station, erecting a low building surrounded by parking, a design that many residents felt was out of character.

Meanwhile, other planning efforts were underway (Linden Hills residents and business owners include a highly motivated group of volunteers). A Main Street Committee of residents and business owners raised funds and installed street trees and decorative lighting in the 43rd and Upton district. A transportation task force also installed several traffic circles and other traffic calming "tests" to try to slow traffic in the adjacent residential areas (of which only two minor traffic circles remain). Finally, a specific zoning overlay district was developed by a parallel task force of resident and business representatives. It restricted parking requirements for certain uses, such as video stores and coffee shops, and established guidelines for building placement and form. The district was applied to the two "traditional" commercial districts (43rd and Upton and 44th and Beard).

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The Transportation Task Force had been working since 1995 to study and implement traffic calming methods and promote bicycle and pedestrian movement. Under the Task Force's auspices, a number of transportation related reports were produced and were used as background information in the planning process.

The task force recommended that a portion of the initial allocation of NRP funds be used to hire a planning consultant to develop a plan for the commercial districts. After a competitive process, the Minneapolis-based planning firm of BRW was selected. Unfortunately, the overlay district was already in place giving the consultant team little opportunity to evaluate it. Rather, the consultants' specific charge was to develop policies, design guidelines, and recommendations for public improvements in all three commercial districts.

As is typical with neighborhood plans, the process was directed by a 10 steering committee of representatives from various NRP committees and the business association. The consultants undertook an inventory of "neighborhood typology" -- elements such as architectural resources, street cross-sections, landscape materials, signage and parking. Interactive methods such as a photo survey (in which committee members used disposable cameras to photograph positive and negative images) and a visual preference survey were used to engage and entertain participants. Public involvement centered on a charrette, or design workshop, an intensive one and a half day process. The charrette generated goals and design alternatives for the 44th Street corridor as a "spine" that links all three business districts, while also generating more specific concept plans for the 44th and France district as the most likely locus for change. The results (discussed in more detail in the following section) included:

- Goals such as increasing the amount, variety and density of housing in the commercial districts and implementing shared parking arrangements;
- Streetscape and traffic calming improvements to 44th Street;
- Concept plans for the 44th and France area that showed its evolution to a more mixed-use, urban environment, with buildings fronting the sidewalk and shared parking to the rear.

If there was a "fatal flaw" in the planning process and the charrette, it was lack of involvement by the business community. Most meetings were publicized in a neighborhood newsletter and in targeted mailings to addresses on and near 44th Street. Business interests were also represented on the steering committee. However, most business owners failed to participate until the charrette was complete. As in many public involvement processes, it is difficult to tell whether businesses were genuinely unaware of the process, whether they may have been aware of it but didn't have time to participate, or whether they felt that their interests were better served by "showing up late.” In any case, they showed up after the charrette and made it clear that they were not pleased with either the results or the process. Most of them favored streetscape improvements but found the idea of introducing housing and other upper-level uses into their commercial districts implausible and alarming.

The consultant team spent the next few months playing catch-up: developing additional concept plan alternatives with business input, and developing and revising land use policies and design guidelines that could be supported, at least in part, by both residents and business interests.

The Framework Plan that resulted from the process was intensively reviewed by both business groups and residents.

Recommendations

Based on the process described above, it is clear that the final report, the *Linden Hills Neighborhood Design Framework*, is not a "consensus plan." The divisions between resident and business interests run too deep to be bridged by a single planning process. However, both groups continue to work together, usually with civility and respect, and many elements of the plan are supportable by both groups. Major elements of the plan include:

Policies and Design Guidelines for the Commercial Districts

Policies were developed to guide the planning process and were grouped into four broad categories which were intended to address the following issues:

- Land Use and Markets
- Built Form
- Greening and Public Realm
- Traffic Movement

The design guidelines used sketches to illustrate principles such as building size, scale and height, facade transparency, relationship to the street and compatibility with nearby "Main Street" buildings (where present).

The policies developed in the category of Traffic Movement included the following areas.

- Shared Streets: Recognize the street as public space, the use of which should be balanced among cars, transit, pedestrians, bicycles and other modes.

- Continuous Sidewalks: Provide a continuous pedestrian path system along all public streets, completing any gaps in the existing sidewalk system.

- Traffic Calming: Continue to implement traffic calming measures within the neighborhood, including the redesign of 44th Street with parking bays and narrowing (bumpouts) at intersections, to improve pedestrian safety and slow traffic.

- Transit Facilities: Provide improved transit facilities to increase transit ridership (i.e. transit shelters integrated into mixed use developments).

- Transit Service: Explore options for redesigning and improving transit service (i.e. through shuttle bus or local circulator) to meet neighborhood and visitor needs.

- On-Street Parking: Continue to provide on-street parking to serve businesses, buffer pedestrians from traffic and serve as a traffic calming measure.

- Surface Parking Replacement: The number of surface parking spaces in the neighborhood should generally not increase.

- Shared Parking: Promote shared parking among existing uses as a way to maximize the use of existing parking and alleviate congestion.

- Alternatives to Conventional Parking: Promote shared parking, transit facilities and bicycle parking in new developments, as a way to minimize the amount of land area devoted to parking.

- Parking Location: Locate off-street parking to the rear of buildings or below-grade wherever possible.

- Employee Parking: Locate employee parking in specified locations where it will not interfere with or pre-empt customer parking.

Site-Specific Analysis and Recommendations

The plan analyzes strengths, weaknesses and potential opportunities in each of the three commercial districts and the 44th Street corridor, and makes specific recommendations for change in each area.

- 43rd Street and Upton Avenue: In this "downtown" district, recommendations centered on simplifying and rationalizing the parking system to facilitate shared parking and remote employee parking.

- 44th Street and Beard Avenue: Primary recommendations were to reconnect this area with continuous sidewalks, allow for gradual intensification of uses, and redesign the undeveloped parkland as a true neighborhood park and central focus for the district.

- 44th Street and France Avenue: As mentioned above, the plan shows various ways in which this district could evolve toward mixed use, ranging from minimal changes such as shared parking to complete redevelopment with mixed commercial, residential and office uses oriented toward the street. The plan makes it clear that none of these options constitute an "preferred redevelopment plan, " and that existing businesses may remain in their locations indefinitely.

- 44th Street: The plan offers a conceptual streetscape design with curb bump-outs or "throating" at intersections, elevated crosswalks at high-foot-traffic locations, street trees, pedestrian-scale lighting and placement of utilities underground.

There were also a number of recommendations for design guidelines that relate to traffic movement. The objective of this set of guidelines was to balance vehicular, transit, pedestrian and bicycle movement and to provide modes of travel. Some of the specific traffic movement design guidelines include the following:

- Parking Location: Locate off-street parking to the rear or buildings whenever and wherever possible. Locate parking to the side of buildings only if an architecturally compatible fence or wall or equivalent landscape material separates it from the sidewalk. The street frontage occupied by parking should not exceed 60 feet per property.

- Pedestrian Routes to Entrances: Ensure that a clear and well-lighted pedestrian route extends from the street or parking lot to all building entrances, including side and rear entrances.

- Bicycle Parking: Design each development parcel with more than five parking spaces to include bicycle parking in a convenient, visible, preferably sheltered, location. Bicycle parking could be used as a substitute for automobile parking, using the four to one ratio provided in the Linden Hills Overlay District.

- Transit Facilities: Each development parcel that includes more than 25 parking spaces needs to provide a transit shelter or other transit facility, if needed in that location.

- Sidewalks: Provide sidewalks along all public street frontages.

- Walkways in Parking Lots: All parking lots serving more than 25 cars should be designed with a landscaped, lighted pedestrian walkway to building entrances or adjacent properties, as needed.

- Off-Site Parking: Permit off-site parking within 500 feet of most uses, if governed by a lease or development agreement for shared parking.

- Service and Deliveries: Use rear alleys or drives for service and deliveries.

- Shared and Internal Drives: Minimize the number of driveways and curb cuts through the use of shared and internal drives.

The plan also includes recommendations for implementation, ranging from zoning changes to site plan review and initiatives that the neighborhood and the city can undertake.

Conclusion: Too Soon to Predict Results

The Linden Hills *Design Framework is a* curious hybrid: it grew out of a neighborhood process, with oversight and guidance by the city's planning department, yet it currently has no official status with either neighborhood or city. Moreover, its recommendations must be implemented, at least in part, with city programs and funding. The plan's cost estimates and funding recommendations are now being integrated into the neighborhood's second and final NRP plan, which will provide the neighborhood with its full complement of NRP funding. However, NRP funds are intended largely as "seed money" to leverage additional funding commitments. Linden Hills, as a solidly middle-class neighborhood, may find it difficult to obtain city or regional funding for streetscape or parking improvements like those recommended in the plan, not to mention new neighborhood parks. Much work will continue to be done by community volunteers, many of whom are "burned out" after four years of committee meetings as part of the NRP process.

When evaluating the feasibility of introducing mixed use and higher densities into established neighborhoods, it is important to remember the regional context. Unlike the East and West coasts, the Upper Midwest still has few examples of successful mixed-use development that can encourage developers to undertake such projects or convince business owners that such changes do not spell economic disaster. In this respect, conditions are not yet ripe for implementation of the larger projects proposed in the plan. However, it is characteristic of established cities that they evolve continuously over time through a multitude of small decisions and incremental changes. The *Framework Plan* is intended to guide but not direct -- this endless and unpredictable process.

Comprehensive Transportation Planning – Providing a Connection Between Plans and Programs

Theresa S. Petko, *Michigan Department of Transportation*

Abstract

Passage of ISTEA in 1991 revamped the transportation planning process and the roles and responsibilities of the Metropolitan Planning Organizations (MPOs) and the state transportation departments. Michigan's transportation planning process was well established, however, there was nothing written clearly describing the process. Confusion over the process and the new planning requirements created a need to revisit and redefine the process within the parameters established by ISTEA.

Development of the revised transportation planning process involved twelve MPOs, Federal Highway Administration and the Michigan Department of Transportation. The revised transportation planning process is now the model for all of the MPOs to follow.

Some of the issues to be discussed include:

- The linkage between the long range plans and the development of the transportation improvement programs has been difficult to describe. The revised planning process for Michigan brings them together in the development of broad program strategies that are then translated into prioritized projects.

- Trust between the agencies was identified as an issue from the workshops held throughout the state. The revised memorandums of understanding clearly explain the roles and responsibilities and the description of the process provides a model for the agencies to follow in developing programs and projects.

- There are four Transportation Management Areas in Michigan and eight MPOs. This diversity requires an approach that can be adaptable to fit the needs of the individual area.

- The Michigan Department of Transportation decentralized creating a need to adjust the administration of the planning process. This created an opportunity to accelerate some elements of the revised process.

The collaborative efforts of all agencies in this process assures that this revised process will continue to serve as a solid foundation for transportation planning in Michigan for years to come.

DOTs And SHPOs: Unifying Objectives Through Programmatic Agreements

David L. Ruggles, *Michigan Department of Transportation*

Abstract

At Michigan DOT, recent changes in both available funding and project programming strategies have resulted in an increase of 2 to 3 times the total number of M-DOT projects requiring environmental review/clearance. To support this ambitious program, management attention was directed towards existing problems in obtaining timely project environmental clearances. A major area of concern in this process was both the time and costs expended in obtaining cultural resource clearances from the State Historic Preservation Officer (SHPO), the federal and state regulatory agency responsible for cultural resource preservation in Michigan. In evaluating the cost-time profile for the cultural resource portion of the environmental clearance process, it was revealed that the cycle time (the time from receipt of a project review request until clearance) for projects with work outside the shoulders was reaching as far as 6,328 hours at an estimated cost of $7,590.00 per project (not including consultant costs) for some projects. Ultimately, it was clear that the existing clearance process was incapable of supporting an increased project program and, in fact, had been insufficient to the needs as they existed before the increased program. Something had to change!

The paper will discuss the problem-solving vehicle the Programmatic Agreement provides for DOT/SHPO cultural resource issues including the following:

- The steps taken as a joint effort between the M-DOT and Michigan SHPO in identifying and analyzing what worked and what didn't work in the cultural resource clearance process.

- The negotiated solutions as expressed within the new Programmatic Agreement between the M-DOT and the Michigan SHPO.

- The improvements realized, the deficiencies identified, what we would do differently, and the options proposed for further process modification using the vehicle of the Programmatic Agreement.

Historically, the operating paradigms of DOTs and SHPOs can be best described as antithetical, with the DOTs emphases on construction/maintenance/improvement and the SHPO emphasis on preservation; and, with both paradigms being created and upheld through our respective legal & regulatory charters of responsibility. The result of this dichotomous relationship has been the increased time and costs associated with extremely high levels of SHPO scrutiny accompanied by extremely low levels of DOT credibility in the area of cultural resource preservation. The Programmatic Agreement offers both parties a complementary means to optimize the implementation of our diverse interests, as well as mitigate significant impacts to project designs, schedules, costs, cultural resources, and, ultimately, public opinion.

Michigan's Five Year Plan--Managing Investments for Long Term Transportation System Improvements

Dave Wresinski and Cynthia VonKlingler, *Michigan Department of Transportation*

Abstract

In the Fall of 1997, the Michigan Department of Transportation began to formalize and enhance methods for the management of investments in new roads and system operational improvements formerly known as the improve and expand program. Through the joint efforts of highway Project Development staff and Project Planning staff, the Five Year Plan for improve and expand projects provides the means for more effective long term management of the program.

In the past, information was available and used to manage individual improve and expand projects. Federal and state program level information was assembled on an as-needed basis. As additional transportation funds became available and as new types of performance objectives were instituted to monitor the effectiveness of investment decisions, management recognized the need to manage the improve and expand projects at a program level on an ongoing basis. Since the process of identifying, evaluating, and implementing improve and expand projects spans several years, management also required a long term view of the program. To facilitate the long term view, projects in the design and construction phases, and also those in the research phase (where needs are being evaluated, alternatives are being considered or environmental impacts are under study) are included in the Five Year Plan.

The Five Year Plan in its current stage of development is presented in a spreadsheet format providing costs per year by phase and other data about each improve and expand project. Data is presented in four projects categories: new roads committed, new roads research, preserve and add capacity committed, and preserve and add capacity research. From the spreadsheet, standard summaries are provided such as totals by year, by region and by project category. This information is tied to geographic files and is one of the new GIS applications in the Department.

This paper will present the details about Michigan's Five Year Plan and will describe some of the problems encountered during development as well as outline plans for the future.

Urban Transportation Network Calibration

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Abstract

Traffic assignment models are much more effective in replicating the observed flow patterns in a study area if the parameters in the link performance functions (LPFs) are allowed to vary to reflect driver behavior and network characteristics. This paper presents an update of some ongoing research into procedures being tested to automate the search for the best LPF parameter values, as well as some phenomena that are likely to affect the choice of the best heuristic search method.

Background

For many years, the standard form of the link performance function (LPF) used in trip assignment in the United States has been

$$t(L) = t0(L)\ [\ 1 + a\ (V/C)^{**}b\ ]$$

where t(L) = the travel time on link L
t0(L) = the free-flow travel time on link L
V = the flow rate on link L, in vph
C = the capacity of link L, in vph, usually at level of service C
a, *b* = parameters that define the shape of the function.

This function is widely known as the Federal Highway Administration (FHWA) volume-delay function, previously called the Bureau of Public Roads (BPR) function. Almost always, the parameter *a* has been given the value 0.15 and the parameter *b* has been assigned the value 4.0. These values appeared in the 1973 publication *Traffic Assignment* [FHWA 1973] without an explanation of how they were determined. At the Second Transportation Planning Applications Conference in Orlando, Florida, Fricker [1989] suggested (and demonstrated) two ways to adjust the FHWA function to accomplish a better calibration to the flow pattern observed in a study area's network. One of the two methods involved making adjustments to free-flow travel times. This method was later determined to be an incorrect way to calibrate a traffic assignment model. It distorts one of the most easily measured link characteristics (free-flow travel time) and produces link functions that are not valid for *forecasting* purposes. The second method involved a systematic adjustment of the *a* and *b* parameters, using a curve-fitting technique. The 1989 paper showed excellent results for a very small test network. Subsequent work showed very good results for real networks of medium size [Fricker and Moffett 1993]. More recent work by Fricker and Moffett has focussed on the nature of the phenomena underlying the calibration activity and the use of improving computer capabilities to tackle larger problems. During this time, others have begun to explore the possibilities of adjusting LPF parameter values. However, an example of this work is fitting an LPF form to the speed-flow curves that appear in the Highway Capacity Manual. We believe our approach is preferable, because it seeks values of *a* and *b* that are based on data taken from the network being analyzed, not from a secondary source. This paper will provide an overview of some of the underlying phenomena and describe some of the research that exploits recent increases in computing power.

The Idea

The systematic adjustment of the *a* and *b* parameters in the FHWA link performance function (or in any other LPF) begins by separating the links in the study area network into their respective functional classes. While our current research is working with several alternative procedures to search for the best *a* and *b* parameters in each functional class, in this paper we will refer primarily to what we call the *grid search* procedure. In the grid search, we simply

- Establish an acceptable range of values for *a* and *b*, such as $0<a<2.0$ and $1.0<b<10.0$ for a typical street link.

- Choose how fine the grid's mesh should be, for example, 0.01 units between adjacent values of *a* and 0.1 between adjacent values of *b*.

- For each combination of *a* and *b*, load the network using the preferred traffic assignment model and record the resulting error measure(s) that indicate how well (or poorly) the loaded flow pattern matches the observed flow pattern.

This procedure is simple in concept, but it requires a large number of computations. With the parameter ranges and grid mesh fineness given in the above example, the number of parameter combinations for each link class is (2.0-0.0)/0.01 * (10.0-1.0)/0.1 = 18,000. In *VillNet*, one of the real networks we are using in our research, there are 117 links in 11 link classes. This means that a traffic assignment algorithm would have to be used 11 * 18,000 = 198,000 times. Because it takes almost one second each time a traffic assignment is made with a Pentium 233 machine, one calibration of the *VillNet* network would take approximately fifty hours. More efficient search techniques are being investigated, but the grid search method has allowed us to identify some characteristics of the calibration problem that will help us choose and evaluate the other search techniques.

The Shelf Phenomenon

Each time the traffic assignment algorithm has been applied to all the link classes in a network, the quality of the assignment is assessed. Among the many possible error measures that can be used to compare each link's assigned flow versus its observed flows [James 1987], the most popular is *percent root mean squared error* (PRMSE). In 1991, Prof. Fricker visited the Institut fuer Logistik und Transport (ILT) at the University of Hamburg, Germany and discussed the network calibration problem with its research staff. ILT researcher Wolfgang Brueggemann ran a small version of the grid search procedure on a PC overnight. The next morning, Brueggemann and Fricker found that the memory of the PC had been exceeded, but enough of the "solutions" had been preserved to permit a careful analysis. The solutions had a particular pattern that reflected the mechanism that is at work when a traffic assignment algorithm is applied repeatedly with small changes in *a* and *b*. Quite often, small changes in *a* and/or *b* will not change the LPF enough to cause changes in how trips are assigned to routes in the network. In other words, several combinations of *a* and *b* will produce the same assigned flow patterns and, therefore, the same error measure. In a three-dimensional plot, where *a* and *b* values form the base horizontal plane, and PRMSE values determine the height of the error surface above the base plane for any combination of *a* and *b*, the resulting error surface will consist of only horizontal surfaces, each a distance above the base plane equal to its error value. We call these horizontal surfaces "shelves". If the values of *a* and *b* change enough to produce a different network loading -- and therefore a different PRMSE value -- the new solution will lie on a new horizontal surface. The solution has "jumped" (up or down) from one shelf to another shelf. To complicate the situation even more, the error surface is not well-behaved. Figure 1 is a plot of PRMSE values for various points in the grid mesh that are defined by combinations of *a* and *b*. Each point lies on a particular shelf, and some adjacent points lie on the same shelf. There are several "pockets" in which low PRMSE values can be found. Some of these pockets are small; other pockets are made up of numerous points lying on the same shelf. Given a choice of a small minimum-PRMSE pocket and a larger pocket with slightly larger PRMSE value, we believe that the latter situation represents a more robust solution to the calibration problem.

Quicker Methods

The shelf phenomenon means that we cannot use traditional techniques to search more efficiently for the parameter values that will produce the lowest possible PRMSE value. However, there are search methods that may be useful in finding good solutions in difficult solution surfaces in a relatively small amount of time. These methods include curve fitting, simulated annealing, genetic algorithms, and tabu search. The grid search method is being used to establish "exact" solutions that will serve as benchmarks against which heuristic solutions can be tested. The heuristic methods will be evaluated as to the time each takes to find a solution, how close to the benchmark solution the heuristic solution is, and whether the heuristic solution is a "robust" one.

Calibration Results to Date

In calibrating traffic assignment models on real, large-scale networks, forty percent root mean squared error (40% RMSE) is normally considered to be a reasonable fit, regardless of the calibration method that is used. In our early research, we chose random values of *a* and *b* within reasonable ranges, loaded the networks using those values, declared the resulting assignment on each link to be its actual ground count, then pretended to "forget" what the randomly chosen *a* and *b* values were. The search for the "true" parameter values began with default values such as $a = 0.15$ and $b = 4.0$. Whatever search technique was used, it was theoretically possible to find a solution with zero error, that is, a solution that duplicates the flow pattern that duplicates the pattern that results from using the randomly chosen parameters. If a search technique could find the zero-error solution, it was eligible for consideration on real networks with unknown parameter values. There are complications associated with finding the best *a* and *b* values when multiple link classes are involved. Changes in the parameter values for one link class often requires that a compensatory adjustment be made for other link classes. The grid search method is not susceptible to these complications, and has consistently found solutions PRMSE values well below thirty percent. Some of the heuristics may be sensitive to these complications, and may not perform well on real networks. This is where the current research is focusing.

Lessons Learned

It must be made clear here that adjusting the shape of the link performance function so that the observed flow pattern is matched as closely as possible produces a set of *a* and *b* values that reflect driver behavior. The "times" that result from using the calibrated *a* and *b* values for any link class reflect the behavior of drivers in the network with respect to links in that class. For example, drivers may choose not to use side streets that have stop-sign-controlled intersections. The *a* and *b* parameter values for these streets are likely to indicate "decision" travel times that are far higher than actual travel times on these links. We call these times "decision" travel times because they help identify which streets are underused. While these values should not be used to directly compute system measures such as vehicle-hours traveled (VHT) during the study period, we think that the calibrated *a* and *b* parameter values offer a much better basis for forecasting driver route choice behavior in future years or under different near-term circumstances. If changes in the network -- e.g., street or lane closures, speed limit changes, a new bridge -- are made, we expect to get a better prediction of the subsequent flow pattern. Some before and after studies are now underway. If direct measures such as VHT are needed, some post-processing of the traffic assignment output must be carried out. We are also considering whether we can also capture the impact on driver route choice behavior of driver information/education programs that are part of the ATIS activities in ITS. Further, if the "decision" aspects of *a* and *b* parameter values can indicate underused links, this may offer worthwhile information to ATIS administrators.

Closing Thoughts

Some loose ends and unresolved issues remain. Many of these items should be resolved this year. As we approach the end of this phase of our research, we would welcome a few networks of medium to large size for us to analyze, provided the network and trip table files can be converted to our format requirements with reasonable effort.

References

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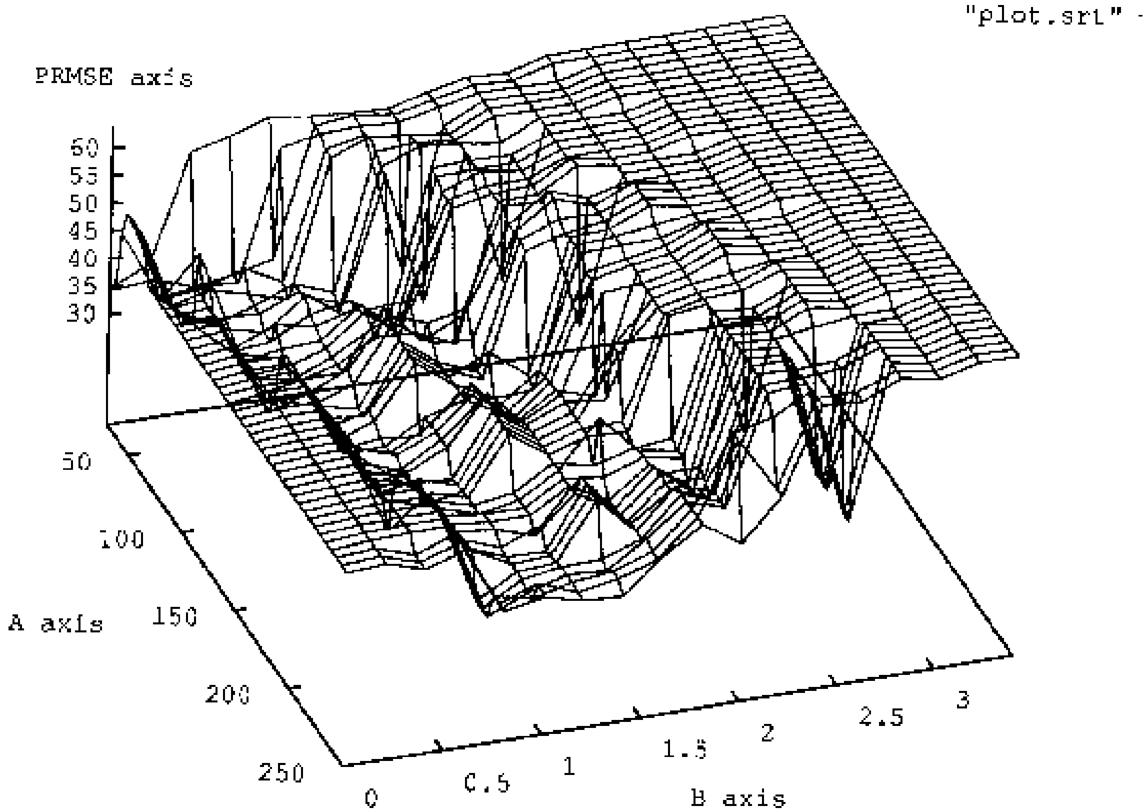
[Fricker 1989] Fricker, Jon D., "Two Procedures to Calibrate Traffic Assignment Models", *Proceedings*, Second Conference on the Application of Transportation Planning Methods, Orlando, Florida, 24-28 April 1989.

[Fricker and Moffett 1993] Fricker, Jon D. and David P. Moffett, "Traffic Assignment Model Calibration When Precision is Essential", ITE 1993 *Compendium of Technical Papers*, Annual Meeting, Institute of Transportation Engineers, The Hague, The Netherlands, 19-22 September 1993, p. 258-261.

[James 1987] James, Matthew L., "Accuracy Evaluation Tests for Assignment Models of Large Traffic Networks", *ITE Journal*, January 1987, p. 36-40.

Figure 1: Grid Search Calibration Results



Improvements In Transportation Planning Network Modeling Mechanics

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Abstract

Several mechanisms are presented to improve the efficiency and accuracy of transportation network model construction and modification. Part I addresses the problem of the application of alternatives to networks. Part II introduces the concept of automatic network defect detection. Part III discusses questions that have been asked. Part IV presents a small commentary on a researcher's perspective on Geographic Information Systems.

Introduction

The advent of inexpensive, powerful computers allows more work to be done by the computer and less by the transportation planner. This paper suggests two major themes that should both improve the quality of transportation models while lessening the burden on the transportation modeler.

Part I – Automation of Alternatives Analysis

Most modelers, when faced with testing several alternatives, copy their base network multiple times, then manually install each alternative on a copy of that base network. Problems arise if, for example, there are errors found in the base network after the copies are made. A 'simple' error of two or three links with the wrong capacity, in an 18 alternative situation means editing 19 networks to repair that bug. It's enough to ruin a modeler's entire day!

If, instead of coding each alternative on a copy of the original network, the analyst codes the *changes* needed to that network to get to an alternative, then it is possible to redo those changes if the base network changes. As a result, when an error is found, all the analyst need do is repair the original network and then apply the changes again to get to the alternative networks. This part describes one way to accomplish this task. It also demonstrates the benefits of such a scheme in terms of the reuse of parts.

Preamble

The techniques described in the remainder of the section are applicable to any transportation model with some modification. These have been fully implemented for TRANPLAN (*apply.pl*) and a research code at Purdue (*apply.sh*). The TRANPLAN [UAG] version was written in Larry Wall's Perl programming language [Wall et al. 1996] while the research version was mainly written in Awk [Aho et al. 1988]. For demonstration purposes, the examples will be from the

TRANPLAN version (see also availability in a later section). The syntax of both realizations has strong Unix overtones, *Because* both of the implementation languages are from that environment.

The ideas here come mainly from programming language source management. Source management is a concept from long ago, mentioned at a high level by Brooks [1995]. It may be insightful to view a transportation network is viewed as a program for a transportation modeling software interpreter. Also important, as a concept, is the perpetual desire of good computer people to have only one copy of any particular change, so that there is only one copy that needs to be maintained.

The general theme is to provide a higher level language to describe modifications to a transportation model. Little sets of modifications can be leveraged to make larger pieces that make up a complete change to a base model.

A Simple Application

At its simplest, a small *apply* program looks like this (this file was called *ac5.apy*):

Example I-1:

```
#
#     ac5.apy
#
#     dpm
#
#     From just west of Dunbar Road at roughly 155th street to the
# existing US 31 right of way at roughly 204th street.
#
#     Includes a full movements trumpet intersection at
#   US 31.
#
#     Nodes 5000-5250
#
log|AC 5 - Line C to Existing Network
#
# Demolition
dl2|8502|9896

# Insert a node
an|5003|13872177|40079700
# Rebuild the link
al|8502|5003|7|  20|S|||1|1|6|2|||2|
al|5003|9896|7|  20|S|||1|1|6|2|||2|

# Mid-part nodes
an|5001|13871536|40077296
an|5002|13872785|40076388

# Connect Line C to the mid-part nodes
al|9906|5002|1|  70|S|||1|46|6|$L|||1|
al|5001|9905|1|  60|S|||1|46|6|$L|||1|

# Connect the mid-part nodes to US31 with High Speed
# Ramps
al|5002|5003|1|  28|S|||1|46|6|2|||1|
```

```
al|5003|5001|1|  30|S|||1|46|6|2|||1|
atmp|5002|5003|5001
```

Some important features should be mentioned at the outset. All *apply* programs allow for comments that start with a pound sign followed by a space ("# '') and run to the end of the line. Blank lines are ignored, which adds further to the readability. This allows a description of what is being done to be included in the program. Second, the pipe character "| ", is used to delimit between fields. Because this is the TRANPLAN version, the field meanings are described in Appendix A.

The first field of each line is a command. Some useful commands, as shown here, are:

- `al` – Add link, which adds a link to the network.
- `an` – Add a node
- `atmp` – Add a turning movement penalty
- `dl` – Delete a link
- `dl2` – Delete a two-way link

After this code is processed by *apply*, it looks like what a normal TRANPLAN modeler might write:

Example I-2:

```
 8502 9896     B
N 5003   13872177   40079700
 8502 50037  20S        1 1 6 2            2
 5003 98967  20S        1 1 6 2            2
N 5001   13871536   40077296
N 5002   13872785   40076388
 9906 50021  70S        146 6 2            1
 5001 99051  60S        146 6 2            1
 5002 50031  28S        146 6 2            1
 5003 50011  30S        146 6 2            1
T 5002 5003 5001
```

The differences in readability are obvious. This output is then fed into the TRANPLAN network editor, which does the changes to the network.

Enhancements

Building on the previous small example, there are three straightforward enhancements that can be made to smooth things even further.

1. Including other source files

In many alternative analysis situations, there are common sections between alternatives. As a result, in keeping with wishing to only have one copy of any coding, the ability to include pieces (or 'parts' if you will) of an alternative to assemble an entire alternative to be applied to a base network is needed. This wish is realized with an 'include' directive. Such directives are directly borrowed from the Unix C language pre-processor cpp.

The syntax is simple:

```
#include "file"
```

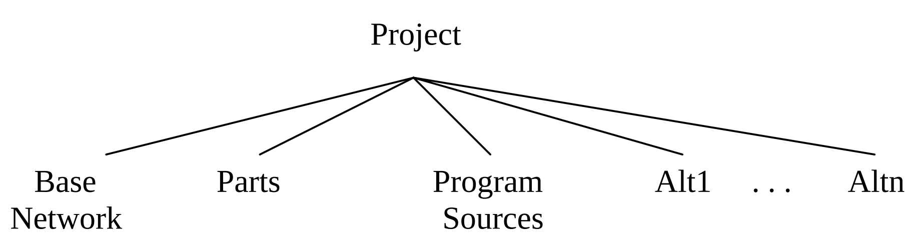
where ‘file’ is the file name of the text to be included instead of the *include* directive. The “#include” directive can be nested indefinitely, so that one file can include another, which can include yet another, ad nauseam.

In application, a full alternative then can be constructed by a simple apply script such as

Example I-3:

```
#
#     Alternative 1 - US 31 Corridor Study
#
#     dpm
#
#     1/1996
#
#     This does *NOT* include "bob's wild interchange" at 103rd street.
#
log|Alternative 1 - Narrow
#
# Number of lanes on the Alternative (ac) parts
v|L|2
#
# Number of lanes on US31 (p1 p2 p3a p3b p4) parts
v|U|3
#
#include "..\parts\spdcap.apy"
#
#include "..\parts\p1.apy"
#include "..\parts\p2.apy"
#include "..\parts\p3a.apy"
#include "..\parts\ac1.apy"
#include "..\parts\ac2.apy"
#include "..\parts\ac4.apy"
#include "..\parts\ac5.apy"
#
```

There are several features to this real example. The parts are included in a separate directory imaginatively called ‘parts’. This keeps them in a common location and allows for deletion of parts if there are any found elsewhere. The constant build-up of models laying here and there needs to be kept to a minimum, so with this methodology often comes a command file (Unix people call it a shell script) that deletes all the files that it knows can be rebuilt. As a result the directory tree becomes:



In each alternative directory is an *apply* file needed to modify the base network into the respective alternative. There is also a file that runs the alternative model. If the sole *apply* file needs a part, it refers up and over to the parts directory to get them. Then in the project directory is the main command file to run all the alternatives and a file to delete all the replaceable stuff. Thus, when the project is done, delete all the old stuff and archive the remainder.

2. Automatically looking up Speed Capacity Data

Another problem that plagues modelers using TRANPLAN and similar modeling packages is the need to repeatedly look up values from a Speed/Capacity table. Because this is another mechanical practice, *apply* does this for the modeler. If the field that needs a value (during an add link or modify link command) is empty, *apply* looks it up in a user-prepared speed-cap table that is normally stored in the parts directory. A small part of such a table looks like:

Example I-4:

```
sc|1|1|2|3500|16875|3325||
sc|1|1|3|3500|25313|3325||
sc|1|1|4|3500|33750|3325||
sc|1|2|2|3775|16875|3575||
sc|1|2|3|3775|25313|3575||
sc|1|2|4|3775|33750|3575||
```

It is generated by a utility program called *spdcap.pl.* (See the "Availability" section later in this paper.) Manually coding a field with a non-standard value will not be over-ridden by *apply*. On the other hand, if the speed/cap table has a problem, just reapplying the alternative after fixing the speed cap table allows for a minimum about of down-stream trouble.

3. Variables

If one looks closely at Example I-1, one will find two $Ls in the added lines. These are variables and are controlled by the variables set in Example I-3. The variable mechanism is very simple and, because the speed-cap tables are looked up, it becomes easy to change large network features. In Example I-3, just changing those variables causes a lengthy facility to change number of lanes. Thus the difference between the 2-lane each way alternative and the 3-lane each way alternative is ONE CHARACTER. The modeler just copies the files from the 2-lane version to another directory and edits the *apply* file to change the 2 to a 3, then re-runs all the automation to build, load and analyze the model.

4. Automatic Parts Construction

Because parts are simple lists of changes to a network, it's also possible to write programs that generate parts. In one problem the authors have worked on, the same style of intersection kept being inserted instead of at-grade interchanges. A simple program that generated all the links at that intersection, given the base number it was supposed to use as a node number, greatly speeded up the creation of each part, while completely eliminating the need to check over the coding of each interchange. The results from the program were checked once in a very detailed way, then all the other interchanges that were built were computer constructed and thus free of coding errors. Here too, see "Availability" near the end of the paper.

Testing pieces

The effort to construct parts pays off in lots of ways. The ability to test what happens to the network if just one or two parts are constructed in an alternative becomes feasible. Traffic volumes can be considered on a piece by piece basis, as well as segment by segment benefit/costs (if one has a benefit/cost post processor). Here is an *apply* file for testing just the part presented in Example I-1.

Example I-5

```
#
#     Upgrade Part 5 - US 31 Corridor Study
#
#     dpm
#
#     6/1996
#
log|Segment P5
#
# Number of lanes on the Alternative (ac) parts
v|L|2
#
# Number of lanes on US31 (p1 p2 p3a p3b p4) parts
v|U|4

#
#include "..\parts\spdcap.apy"
#

log|Line J

an|9919|13863603|39987416
an|9920|13864349|39986680
al|9919|9892|4|  01|S|||4|49|4|2|||1
al|9892|9920|4|  01|S|||3|49|4|2|||1

#include "..\parts\p5.apy"

log|Line K
al|9893|9921|4|  01|S|||3|49|4|2|||1
al|9922|9893|4|  01|S|||4|49|4|2|||1
```

This method requires some additional planning on the front end of the alternatives coding, but ultimately yields very large payoffs when time is tight and errors are found late in the process.

Once the network is constructed, how does one find defects in it?

Part II – Automated Network Defect Detection

Transportation networks are notoriously complex and filled with detail. As a result, it is often very difficult to detect or repair errors that are introduced in the network, either when it is being originally constructed or later when modifications are being done to it. This section introduces automated defect analysis of network problems.

The following ideas are broken up into three parts:

A. a simple review of the unloaded network for problems
B. a look at the network after it has been loaded
C. some higher-level heuristics are presented for looking at more complex problems

Any of these techniques could be done by a human analyst, given sufficient time. By automating these checks, it allows simple problems to be found very quickly and routinely, leaving the analyst to deal with higher-level issues.

These techniques are not specific to any particular modeling package. Some of them have already been implemented in some commercial software. This is not presented as a detailed implementation guide but more as a list of items that should be considered. The list of defects that should be detected under each level also grows as more real-world defects are discovered. See the section on “Programmability and Extensibility” later in this paper.

Unloaded Networks

An unloaded network is a network that has been constructed, but has not yet had model results placed on it. These tests look mostly at the structure of the network.

1) Disconnected Nodes – A ‘disconnected node’ is a defined point in model space that doesn’t have any connection to the transportation network. There are many reasons that disconnected nodes occur. Some are:
   - The node was put in place when the base map was being created because it would be needed later (for perhaps a different alternative being applied). In this case, it is probably okay. (See “Programmability and Extensibility” below.)
   - The node is a by-product of importing a network and is therefore extraneous.
   - The node is the result of a network modification, in which its respective links were deleted but the actual node wasn’t removed. This happens often in GIS environments, when nodes are not explicitly highlighted or in networks where the nodes are stored separately from the links.
   - The node looks like it is attached, but it really isn’t. This often happens in graphical editing of a network.

   Disconnected nodes can be found by traveling all the links in a network and marking a node as ‘touched’ if a link connects to it. Then after that is completed, all nodes that are not marked as ‘touched’ are ‘disconnected’.

2) Unreachable Nodes – An ‘unreachable node’ is a point in model space that cannot be traveled to, but may (perhaps) be traveled from. There are several reasons that can occur:
   - The node is fully connected to the network, but:
     - the capacities to reach the node are zero
     - the speeds to reach the node are zero
     - the travel times to reach the node are very large values, thus effectively precluding the use of the node
   - The node is at the end of one or more one-way link(s) that point away from the node.

   Unreachable nodes can be detected by doing several tours of the network, looking at reachability in terms of direction, capacity, speed and travel time. Each is considered separately, so that each can be brought out as an error individually.

3) Unattached Links – An 'unattached link' is a link that is not reachable from the majority of the network. There may be one or more links in a set of unreachable links. These occur because:
   - Network editing caused a link or links (sometimes called a subnet) to be disconnected.
   - The link is fully connected to the network, but:
     - the capacities to reach the link are zero
     - the speeds to reach the link are zero
     - the travel time(s) are large enough to preclude use of the link
   - The link is part of sub-net that can only be reached by going the wrong way on one or more one-way streets.

   As with the previous step, the network is traversed several times, taking into account at different times direction, capacity, speed and travel time.

4) Discontinuous Networks – A discontinuous network expands the idea of unattached links, adding centroids that can produce and consume trips. In essence, this problem is two or more networks (probably unintended) running in the same model. Traversing the network from a single point that didn't fail the earlier checks, then seeing if there are any other centroid-connected links that were not visited, will detect this anomaly.

5) Stub Links – Stub links are those links that are fully connected to the network, but because there are no trip producers or consumers at the end, there will be no trips on the links. Stubs are easily detected by traversing the network from each centroid assuring that there is a way to travel to all the links in the network on the way to another centroid.

6) Link Lengths – Many modeling systems attach the network to a geographic coordinate system. (In the US it is usually the USGS State Plane Coordinate System.) This provides a measure of distance that should be reported on a link (plus or minus the curvature and terrain a link covers). Irregular links are those where the link distance between the end points is either:
   - Too short to cover the coordinate system distance. This is clearly an error.
   - Longer than some programmed margin for curvature.

   Links are tested one by one computing the distances between their end-points, then comparing that value to the link coded distance.

7) Invalid Specific Field Data – Although specific to the modeling system that is being used, there are a large number of specific checks that can be made. Some examples are:
   - Missing data
   - Capacities that don't match facility types and number of lanes. Starting with the HCM [1994] as a basis, the facilities are compared to their coded capacities.
   - Improbable speed limits
   - Traffic control devices on interstates
   - Traffic counts that exceed link capacity by too great a margin

   These checks can be easily be made by a link by link traversal of all the links in the network.

8) Adjoining Link Facility Types – Often, to get accurate coding of networks, each direction of a facility is coded separately. This check assures that the facility types match for each direction.

9) Matching Traffic Control Devices – In models that allow for the coding of traffic control devices, this assures that each approach to an intersection has appropriate traffic control devices. These fall into two major classes:
   - All approaches have the same devices
   - Opposite approaches are stop-controlled.

   Links that are the result of merges (such as a ramp approaching an interstate) are usually not coded as 'yields', so these are not checked for.

   A sideline to matching TCDs is that intersections that are not intended, but for one reason or another got coded (like networks imported from an external source) become errors that the analyst then needs to evaluate.

   Building a table of all nodes then attaching the appropriate links to each node does the first part of the evaluation. Once this table is created, then each node's approaches are evaluated. If the spatial relationship of the approaches is known, then it is easy to determine which approaches match each other. Otherwise, a heuristic looks at facility name, facility type and capacity and attempts to estimate which links belong to each other.

Loaded Networks

1) Conservation of flow at nodes – Though a simple computation, modeling systems sometimes keep vehicle flows as real numbers instead of integers. This check assures that each node has the same number of vehicles departing as entering.

2) Conservation of flow at links – Less considered than node conservation is link conservation of flow. In some modeling systems it is not possible to lose this balance of flow, but it is included here for those systems that can lose a vehicle now and then. This check assures that all the vehicles entering a link depart it.

3) High Volume/Capacity Ratios – The most common indicator of problems in a highway transportation network model is a strange V/C ratio. This check evaluates each link and determines if the V/C is greater than the limit set by the analyst. The defaults are done by facility type.

4) High Travel Times/Very Low Speeds – The second major indicator that a highway transportation network has problems is unreasonably low speeds or very high travel times. This check looks for speeds below a limit set by the analyst on a link by link basis.

5) Volume match Facility Type - Even with correct capacities, sometimes links have the facility class inappropriately coded. This check looks at the volumes and compares them against the typical flows that would be found on that facility class.

6) Flows through centroids – Many commercial software packages do not permit flows between two centroids to go through an intermediate centroid. Even when the software allows it, this is seldom a desirable situation. It should be brought to the attention of the analyst for possible resolution.

Higher-level Methods

Higher-level methods are those that are significantly more sophisticated than those in the preceding sections, which was mostly making sure that the accounting of the model works appropriately. Usually higher-level methods exploit knowledge that the network is a transportation network. Because of their complexity, some of them will be appropriate to certain modeling environments.

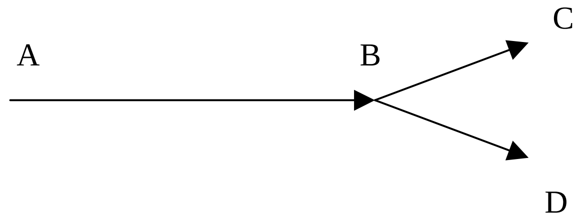
1) Link Lengths – In networks, especially those that are not tied to a geographic coordinate system, it is sometimes possible to evaluate the lengths of links that do not make sense with respect to the links around them. The key here is to find link relationships that require a geographic relationship, then exploit this relationship.

   A simple example of this is a triangle. The three points and three sides determine the distance each point will have to the other points, with some margin for curvature and area topology. Shapes with four or more sides, on the other hand, have no distance requirements other than the overall length of the object can't be greater than half the sum of all the sides. Using straightforward topology, it is sometimes possible to check at least some of the link lengths by exploiting these relationships.

2) 24-hr flow balance – In transportation networks, a trip maker typically returns to where he/she started. This argues that the 24-hour flow on any particular facility should be roughly equal in each direction. This check provides the analyst with changeable out-of-balance limits according to FHWA facility type [FHWA 1989].

3) Conservation of flow capacity – It is rare for a major facility to simply end in a minor facility. Traversing the network, looking at each node's capacity in versus capacity out, is a useful measure of the network's correctness. This is controlled by the analyst, using a modifiable parameter. In case 1 below, there is sufficient capacity to take the flow from A-B into B-C and B-D. In case 2, there is a net loss of capacity (2000 > 900 + 950), and thus there may be a problem with the network coding.

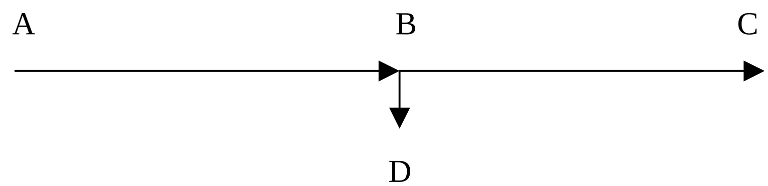
   <u>Example II-1:</u>



Link	Capacity – Case 1	Capacity – Case 2
A-B	2000	2000
B-C	1800	900
B-D	1850	950

4) Sensible Flow Analysis – One major sign of a defective transportation network model is irrational flows leaving the primary route systems. This check is done in several ways:
   - If the flow is greater than a programmable percentage of the capacity (see Example II-2), then there's probably a problem.
   - Flows that make more turns than they need to usually point to problems. A comparison of the shortest path by distance versus shortest path by time points these out (See Example II-3).

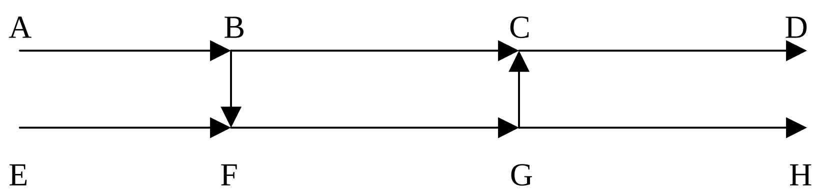
Example II-2:



Flow	A-B	B-C	B-D
Capacity	**2000**	**2000**	**1200**
Volume	**1800**	**800**	**1000**
V/C	**0.90**	**0.40**	**0.83**

This shows that a greater percentage of trips by V/C went to a lower capacity facility than continued along the higher capacity facility by a V/C of 0.3, indicating a possible error. Once again, these parameters are programmable to the specific facility type.

Example II-3:



Link	Capacity	Flow	V/C
A-B	2000	1400	0.70
B-C	200	200	1.00
C-D	2000	1400	0.70
B-F	1800	1200	0.67
E-F	2000	600	0.30
F-G	2000	1800	0.90
G-H	2000	600	0.30
G-C	1800	1200	0.67

Because the capacity of B-C was miscoded, the flow was rerouted when the network was loaded. This causes the shortest path to not have the shortest time in unloaded conditions and also adds more turning movements. These problems are detected by building both shortest path and shortest time trees and then comparing their routes with a heuristic to account for acceptable diversions from the shortest length path.

5) Exceptionally low facility utilization - This test looks at the flip side of excessive V/C ratios and looks for facilities that are grossly underutilized. The default minimum volumes are modifiable by each facility type.
6) Flows through a node match use – In some modeling systems, the flows that occur at an intersection are modeled in detail. This looks at the V/C of each movement and considers the reduced capacity brought about by the presence of traffic control devices.

7) Interchange construction – Heuristics allow the review of normally configured Interstate interchanges. It looks in part at:
   - Where there is an exit, is there an entrance?
   - Where there is an entrance, is there an exit?
   - Are the directions of the ramp links coded correctly?
   - Are the capacities within the range of typical ramps?

Programmability and Extensibility

Each of the preceding possible defects has the possibility of being correct under odd circumstances. Because of this, it is necessary that the analyst be able to turn off a particular defect detection feature, either totally or at a specific point in the network. This permits an analyst to avoid being swamped with comments regarding apparent defects that have already been checked in previous runs of the defect analyzer. The general cycle will be to run the analyzer, fix the problems and turn off defect detection for locations that have 'errors' that are not really errors. Then repeat the cycle. Ultimately, the network should generate no errors, because they have either been repaired or the analyzer has effectively been told "it's ok the way it is." When changes are made, only things that really need to be considered are brought to the analyst's attention. This repeated error checking is called 'regression testing' in the computer science literature [Beizer 1984]. Then, for the life of that network, the "errors ok" file travels with the network to save future repetition of the defect detection effort.

As previously noted, the list of defects that should be found and reported continues to grow. It is important that the program be sufficiently modular and well laid out, so that it is easy to add another feature to the analyzer.

Part III – Some Questions and Answers

Q: How does one implement alternatives application in a graphical environment?
A: This is a difficult problem. There are two perspectives to consider.

At a low level, the problem becomes "what will fit within the design of the graphical environment?" Something as simple as capturing keystrokes and mouse movement and clicks might work just fine. Other environments, where there is no scripting available, present greater problems. Whatever the case, being able to edit the stream of changes is important, so that long and complex actions can be slightly modified without being completely redone. The ability to combine sets of changes has merit, as shown in Part I.

The high level perspective is that of what is trying to be accomplished. The original alternative specification probably was something that was very high level, such as "add one lane in each direction on U.S. 31 between 103rd and 116th Street". This ultimately should be the goal of an alternative applying software, because it describes in succinct way the real scope of the alternative. GIS specification of such a textual instruction wouldn't make sense, because it would take more time to do and have a much higher probability of error.

Q: Won't contemporary GISs fix all the defect detection?
A: No, for several reasons. Geographic Information Systems still require that a human look at the network before going on. Perhaps the analyst will catch the big problems, but what about the small ones? With automation, the known state of defects can be assured. Second, often in the rush to get a project complete, the analyst may look at a problem and not recognize it as a problem. Haste makes waste, but with these technologies, there should be less waste. In any case, a network can never be declared 'good enough' without careful human inspection.

Q: Are these techniques applicable to models that don't use link and node data representations?
A: Yes. Although the details of low-level parts of defect detection may be guaranteed by the implementation, the higher level issues like bad V/C values remain.

Q: Will defection detection lead to the importation of poorer quality networks?
A: Yes. This has both good and bad aspects. It will make projects that couldn't be done on an economic basis possible, because a horrible base network can be converted into some useable form relatively quickly. On the other hand, the early 1960s expression 'Garbage In-Garbage Out' implies that there is a lower limit that shouldn't be crossed in data import quality. Many consultants have previously attempted to use early U.S. Census Tiger Files as a base network, much to their peril. Defect detection tools may give analysts a quick assessment as to the quality of the network and thus allow them to decide which source to use for their base network.

Part IV – GIS Commentary

The authors, as researchers in the transportation planning community, are always interested in the pre-, mid- and post-processing of data by specialized software of our own making. As a result, it is critically important that an easy path for both importing and exporting GIS networks be available that can be scripted for repeated use.

From outside the GIS environment, something along the lines of

```
C:> GIS_PROGRAM EXPORT_SCRIPT EXPORT_DATAFILE.txt
```

and for importing

```
C:> GIS_PROGRAM IMPORT_SCRIPT IMPORT_DATAFILE.txt
```

will save considerable effort in working with GIS systems, while also working to advance the state of the art.

As noted in Parts I and II, the ability to easily export data for analysis can have very high payoffs. Modelers will not use this kind of technology if it is too difficult to use.

Availability

The lead author's intent is that code to support these ideas be available at www.vutar.com. See that web site for more information.

Acknowledgments

The alternatives application idea was originally used in a research project turned civic lesson in West Lafayette, Indiana [Fricker 1991]. Its output was configured for an updated version of a 1960s UCB program now called "load8". It later was turned into a TRANPLAN pre-processor that allowed for the automated application of several dozen alternatives to be tested in very quick order on a project sponsored by INDOT and executed by Bernardin Lochmueller and Associates, Inc of Evansville, Indiana.

Defect analysis of networks came about as a small set of post processors for "load8" and then TRANPLAN. It is still under development.

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Appendix A: TRANPLAN field codes

In the BUILD HIGHWAY FUNCTION of TRANPLAN, the following format is required for the "add link data record".

Record Columns	Field Name		Record Columns	Field Name
1-5	ANODE		45	Same data for B-A direction as for A-B?
6-10	BNODE		46-49	Speed or Time value
11	Assignment Group Code		50-53	Speed or Time value
12-15	Link Distance		54-55	Direction Code
16	S for speed, T for time		56-57	Link Group 1
17-20	Speed or Time value		58-59	Link Group 2
21-24	Speed or Time value		60-61	Link Group 3
25-26	Direction Code		62-67	Capacity
27-28	Link Group 1		68-73	Counted Volume or 2nd Capacity
29-30	Link Group 2		74-80	Comments
31-32	Link Group 3			
33-38	Capacity			
39-44	Counted Volume or 2nd Capacity			

Appendix B: *apply* for GIS-based models?

One of the sadder things that have happened to modeling of late is the great reduction of programmability of models by scripts. The use of simple tools like 'apply' allow the leverage of a single effort over many networks isn't yet possible in most graphical models. It is, however possible if one is innovative.

Most graphical models have a means of unloading a network back into some textual form. If one were to code a 'part' in a graphical model, then unload it to the text based-form and compare it to the text version of a base network, the total change that was done would be reflected in the differences. A standard tool, called *diff*, was written for Unix to do this. Since then, this same tool has been ported to many other environments, including MS-DOS.

With the so called 'context diffs', where to go next? The same programmer who wrote *Perl* wrote (much earlier) a program that is called *patch*. Patch's entire purpose is to take the result from *diff* and apply it to a source file that is either identical or *reasonably similar* to where it came from. Thus several alternative parts could be attached to a base network with 'patch'.

This sort of thing should work in theory, but the authors have yet to try this "sleight of hand".

Use Of Facility Specific Volume-Delay Functions: A Caution For Relatively Congested Travel Models

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Shi-Chiang Li , *Florida Department of Transportation*;
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Abstract

Most travel models in the past have used a single volume-delay function in traffic assignment. Beginning this decade, more and more travel models are using multiple volume-delay functions. The Travel Model Improvement Program (TMIP) has identified the use of multiple functions as an effective way to improve travel models. Models using multiple functions are able to account for the differences in the way, for example, that freeways and signalized surface streets operate. The use of multiple volume-delay functions has been discussed extensively in the literature. This paper will summarize the recommendations in the literature and then will present several recent model validation and forecast studies where multiple functions are used. A major finding is that multiple volume delay functions must be tested using future year data to ensure that they will produce reasonable travel forecasts. This paper will address a few other related parameters (the relationship between practical and possible capacity, peak hour factors, speeds and capacities) and their effect on multiple volume-delay functions.

Benefits of Using Multi-Point Assignment (MPA)

Robert Shull and Brent Cain, *TModel Corporation*

Abstract

Many techniques have been tried to improve the accuracy of the assignment process in travel demand models. As models are being used for more purposes, it is important to improve the accuracy of the link assignments and the turning movement outputs.

Typical centroid connectors from the zone centroid to the network do not always replicate the paths of travel adjacent to the zone. Trips are typically assigned to use the shortest path centroid connector and do not reflect the multiple access points around the perimeter of the zone.

Multi-Point Assignment (MPA) is one technique that permits the modeler to assign the percentages of trips to be assigned to various points on the network in and around the zone. The result is similar to having many times the number of zone centroids, but without the accompanying disaggregation effort and computation times.

This paper discusses the implementation of the MPA technique for three transportation models. The models discussed include the City of Santa Fe, New Mexico, the City of Issaquah, Washington, and the Village of Naperville, Illinois. The efforts and methods of implementing MPA are discussed for each of the models. Model calibration validation measures are compared for the three models with and without the implementation of Multi-Point Assignment. The measures compared include screenline volumes and deviations, link volume deviations, link volume R^2 and Root Mean Square Error (RMSE).

Conclusions and recommendations are presented on the application of this technique.

Improved Speed-Flow Relationships: Application to Transportation Planning Models

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Abstract

The Year 2000 edition of the Highway Capacity Manual (HCM) will contain several new chapters providing guidance to planners on how the HCM can be used in transportation planning models. This paper describes a new speed-flow curve recommended by the new HCM for use in planning models and illustrates the application of this new speed-flow curve in the San Francisco Bay Area. This new speed-flow curve is called the "Akçelik " curve.

Previous research by Dowling, Singh and Cheng demonstrated that the Akçelik speed-flow model produces significantly more accurate speed estimates than the standard Bureau of Public Roads (BPR) equation traditionally used in planning models. As has been shown in the wealth of speed-flow data gathered for freeways and other facilities, the Akçelik speed-flow curve is relatively insensitive to increases in traffic volumes until volumes approach capacity. Then the speeds predicted by the Akçelik curve drop fairly rapidly (at the rate predicted by queueing theory). The Akçelik predicted speeds however do not go as low as those predicted by the standard BPR curve for extreme volume/capacity ratios (greater than 2.00 v/c). This is because the Akçelik curve has the property of maintaining a linear increase in link travel times for v/c ratios greater than 1.00. This linear increase in travel times for v/c ratios greater than 1.00 is also in accordance with queueing theory and has been born out in simulation model results.

This paper shows a specific application of the Akçelik curve to the San Francisco Bay Area. It was found that the Akçelik curve did not adversely affect equilibrium assignment model run times. The computation times were similar for both the Akçelik and a variation of the BPR currently used by MTC. The Akçelik curve however resulted in a significant (and the authors believe more realistic) lowering of the estimated mean systemwide speed by 3 to 6 mph (5 to 10 km/h). The Akçelik curve also results in more realistic assigned traffic volumes that tend to cluster more closely around a v/c ratio of 1.00 with much fewer links with v/c ratios in excess of 1.5 than obtained with traditional BPR curves and their variants.

Introduction

The Year 2000 edition of the Highway Capacity Manual (HCM) will contain 6 new planning oriented chapters designed to give planners guidance in the estimation of link and node capacities, node delay, and link speeds for use in transportation planning models. Among the various recommended analytical procedures contained in the new HCM is a new speed-flow curve that better fits current data on facility operations than the traditional Bureau of Public

Roads (BPR) which was originally fitted to data in the 1965 edition of the Highway Capacity Manual. The new speed-flow curve is called the Akçelik curve. Variations of this curve are already used elsewhere in the HCM to predict the delays at signals and at stop signs.

Previous research by Dowling, Singh and Cheng (1) into the Akçelik speed-flow model (2) demonstrated that the Akçelik provides more accurate speed estimates and does not adversely affect model computation times. This research showed that the results of the highway assignment for the year 1990 using the Akçelik link congestion function compare well with the results of the highway assignment using the MTC link congestion function (3). The Akçelik link congestion function has the added advantage of better simulating link travel times for oversaturated conditions (4).

This paper investigates the Akçelik model from a forecasting standpoint and compares various forecast years (2000, 2020) to analyze how the steepness of the Akçelik curve impacts speeds for future years.

Background

A speed-flow function predicts facility speed as a function of traffic flow. They are based on empirical research (5).

1994 HCM Speed-Flow Curve

The 1994 HCM presents a speed-flow function (see Figure 1) which is derived empirically. The drawback of using this function is it's inability to predict speeds for volume-to-capacity ratios in excess of 1.0. This limits it's use in planning models where demand can exceed capacity resulting in volume-to-capacity ratios in excess of 1.0.

BPR Curve

Traditionally the BPR function (6)(see Figure 1) has been used for planning models. This curve was based on the 1965 HCM which was parabolic in shape, and speed was fairly sensitive to increasing flows. The BPR curve is as follows:

$$\text{Congested Speed} = (\text{Free-Flow Speed})/(1+0.15[\text{volume/capacity}]^4)$$

The problems with the BPR curve is that it overestimates speeds for volume-to-capacity ratios in excess of 1.0 and underestimates speeds for volume-to-capacity ratios less than 1.0.

MTC Speed-Flow Curve

The 1994 HCM speed-flow relationship had a more gradual slope with constant speed for higher level of flows (see Figure 1). For volume-to-capacity ratio of 1.0, the congested speed is only 5 mph less than free-flow speed. To account for the 1994 HCM speed-flow relationship, the BPR curve was updated (3) as follows and called the "MTC" curve (see Figure 1):

$$\text{Congested Speed} = (\text{Free-Flow Speed})/(1+0.20[\text{volume}/\text{capacity}]^{10})$$

The coefficient was changed to 0.20 instead of 0.15, and the exponent was changed to 10 instead of 4.0. Also capacity values at level-of-service “E” (operations at capacity according to 1994 HCM) were used instead of practical capacity (level-of-service “C” according to 1965 HCM). This function followed the 1995 HCM speed-flow relationship very closely and gave good results for speed and volume validation when applied to the full MTC model system. To more closely reflect local conditions, the speed drop at v/c ratio of 1.0 was 10 miles instead of 5 miles, e.g., for a free-flow speed of 65 mph, the congested speed at a v/c ratio of 1.0 is 55 mph.

The Akcelik Curve

The Akçelik speed-flow model (2) is as follows:

$$t = t_o + \{ 0.25T[(x-1) + \{ (x-1)^2 + (8J_a x/QT)\}^{0.5}]\}$$

where: t = average travel time per unit distance (hours/mile)
t_o = free-flow travel time per unit distance (hours/mile)
T = flow period, i.e., the time interval in hours, during which an average arrival (demand) flow rate, v, persists
Q = Capacity
x = the degree of saturation i.e., v/Q
J_a = the delay parameter

Link Travel Time Comparisons

A comparison of the travel times in Figure 2 shows that the BPR curve is fairly insensitive to increasing flows beyond v/c ratios of 1.0. The travel time for the Akçelik curve increases linearly beyond v/c ratios of 1.0, whereas the MTC curve travel time increases non-linearly beyond v/c ratios of 1.0. For v/c ratios below 1.5 the Akçelik curve predicts higher travel times than the MTC curve. However, beyond v/c ratios of 1.5 the travel time for the MTC model increases non-linearly which is contrary to queuing theory compared to the Akçelik curve which increases linearly. As such, the MTC curve overpredicts travel time for links with v/c ratios in excess of 1.55.

Bay Area Forecast Comparisons

This section discusses the results of the various curves investigated for this analysis. Comparison between the different curves is conducted based on computing times, convergence achieved, systemwide average speeds, speeds and volumes on selected facilities, vehicle-miles traveled, vehicle-hours traveled, speeds by facility types, and vehicle-miles by facility type.

Test Protocol

The various speed-flow curves were tested on the MTC highway network covering the San Francisco Bay area. The Year 2000 network has 32,114 links and 15,730 nodes. The Year 2020 highway network has 32,476 links. There are a total of 1120 zones of which 21 are external zones. The highway network has eight facility types and six area types. The facility types are: freeway-to-freeway connectors, freeways, expressways, collectors, freeway ramps, dummy connectors, major arterials, and metered ramps. The area types are: core, central business district, urban business district, urban, suburban, and rural. The free-flow speeds and capacities are based on the Highway Capacity Manual and take into account the capacity decreases due to heavy vehicles and weaving.

The Akçelik curve was tested with values of J_a as follows:
freeways=0.1, freeway-to-freeway connectors=0.1, freeway ramps=0.167, expressways=0.2, arterials=0.4, metered ramps=0.4, and collectors=1.2. These are based on Akçelik 's representative parameter values (4).

The software used for this analysis is MINUTP (1993 version). Coding speed-flow curves which are of the functional form of BPR curves are relatively simple to code for this version. However, to code the Akçelik function, capacity restraint factoring curves had to be coded. Since each facility type and area type has a distinct curve, forty-eight capacity restraint factoring curves had to be coded. This involved coding the curve volume/capacity values and corresponding factor to multiply the link base impedance by to obtain the congested impedance.

The highway assignment for 1990 was conducted for a.m. peak hour. For years 2000 and 2020 the highway assignment was conducted for a 2-hour a.m. peak period. For the peak period highway assignment, the facility capacities were doubled and the trip table used was for a 2-hour time period.

Effect of Curves on 1990 Validation

The Akçelik curve was compared to the MTC curve based on the root-mean square error (RMS). The RMS error was based on a comparison of observed speeds (using floating car runs) with speeds predicted by the models for 119 selected freeway segments over the San Francisco Bay area. The 119 selected freeway segments varied in length from 1 mile to 9 miles and provided good coverage by including 550 miles (41 percent) of the total 1,340 center-line freeway miles in the highway network. The RMS error for the MTC curve was 10.1, compared to BPR which was 10.8, Updated BPR was 10.4, and Akçelik was 9.83. As such, the Akçelik curve appears to be encouraging.

Effects of Curves on Computation Times

A significant area of concern is the computing time it takes using the Akçelik curve compared to the MTC curve. As presented in Table 1, the computing times are fairly similar. Also the Theta factor which reflects the degree of convergence appears to be similar or slightly better for the Akçelik curve compared to the MTC curve.

Effects of Curves on Systemwide Results

The average systemwide speed for the Akçelik curve is lower as compared to the MTC curve for all scenarios. As shown in Table 1, the average systemwide speed for the highway network as a result of the highway assignment is consistently lower by 3 to 6 miles/hour for the Akçelik curve compared to the MTC curve.

Effect of Curves on VMT by Facility Type

The vehicle miles by facility type are shown in Figure 3. There is an overall increase of vehicle miles for the Akçelik curve compared to the MTC curve. There is a decrease in vehicle miles for the freeway system, and an increase in vehicle miles for the arterials. This shows that more travel is taking place on the arterials for the Akçelik curve as compared to the MTC curve which may explain the reduction in overall systemwide average speed for the Akçelik curve.

Effect of Curves on Speed by Facility Type

Speeds by facility type (Figure 4) show that the speeds on all facility types are lower for the Akçelik curve compared to the MTC curve.

Effect of Curves on Distribution of VMT and VHT by V/C Ratio

A distribution of vehicle-miles and vehicle-hours by V/C ratio is shown in Figures 5 and 6. The VHT and the VMT for the Akçelik curves is relatively higher for V/C ratios 0.5 to 1.1, after which the drop in VHT and VMT is fairly steep.

Effect of Curves on Regional Speed Profiles

Figures 7, 8 and 9 show the distribution of vehicle miles traveled (VMT) by average speed for the MTC and Akçelik curves. The distribution for year 1990 is bimodal (two humps) whereas the distribution for years 2000 and 2020 is tri-modal (three humps). The first hump occurs at the free-flow speed for non-freeway facilities. The second hump for year 1990 and the third hump for years 2000 and 2020 occurs at the free-flow speed for freeways. The second hump for years 2000 and 2020 occurs at the free-flow speed for expressways.

For all the years, the Akçelik curve predicts a higher percentage of VMT operating at speeds greater than 60 miles per hour and lesser than 30 miles per hour. For the years 2000 and 2020, the Akçelik curve also predicts a higher percentage of VMT operating at speeds in the vicinity of 50 miles per hour. This results in a net areawide average speed reduction of 3 to 6 miles per hour for the Akçelik equation as compared to the MTC curve.

Conclusions

A comparison of volumes and speeds observed on the San Francisco Bay Area freeways shows that the Akçelik curve performs well. A comparison of speeds for different facility types shows that the Akçelik curve reduces speed on all facility types. The Akçelik curve is a superior curve compared to the MTC curve as each facility type has a different value of J_a (delay parameter).

Compared to the MTC curve, there is some redistribution of vehicle-miles for the Akçelik curve. The vehicle-miles on the freeways is reduced whereas the vehicle-miles on the arterial increases.

The computing time for the Akçelik curves is approximately the same as the MTC curves and the convergence appears to be better (see Table 1).

The Akçelik curve is about as accurate as the MTC curve and has the advantage of predicting the linear impact of congestion on speeds. It predicts lower speeds for congested conditions which is desirable.

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Table 1
MTC AM Peak Hour and Peak Period Highway Assignment Statistics

	Theta-Equi Factor	Trips Assigned	Veh. Dist. (miles)	Vehicle Hours Free-Flow	Vehicle Hours Estimated	Vehicle Hours Delay	Computing Time(min)	Avg. Speed (mph)	Computing Time/Iteration
Peak Hour Assignment (8 Iterations)									
Standard BPR-1990	0.210	909,001	8,527,882	174,297	190,337	16,040	36 mins 42 secs	44.80	4.59
MTC Curve-1990	0.084	909,001	8,632,456	178,438	202,125	23,687	36 mins 45 secs	42.71	4.59
Akçelik-1990	0.078	909,001	8,751,266	182,739	228,790	46,051	37 mins 30 secs	38.25	4.69
2-Hour Peak Period Assignment (16 Iterations)									
MTC Curve-2000	0.079	1,677,410	17,940,271	367,985	405,603	37,618	58 mins 13 secs	44.23	3.64
Akçelik-2000	0.040	1,677,410	18,085,794	375,421	437,416	61,995	59 mins 05 secs	41.35	3.69
MTC Curve-2020	0.026	2,049,740	22,469,943	458,761	541,236	82,475	60 mins 07 secs	41.52	3.76
Akçelik-2020	0.031	2,049,740	22,773,810	473,225	638,594	165,369	61 mins 48 secs	35.66	3.86

Figure 1
Comparison of BPR, MTC, Akçelik and 1994 HCM Speed-Flow Functions for Freeways

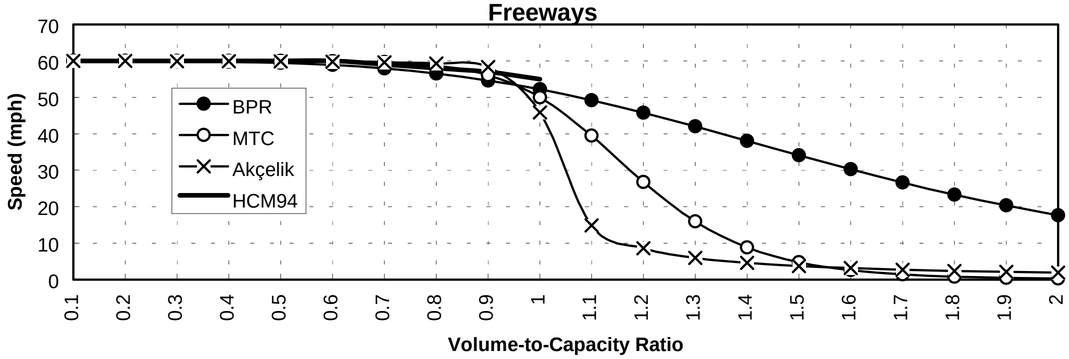


Figure 2
Comparison of BPR, MTC, Akçelik, and 1994 HCM Travel Time Functions for Freeways

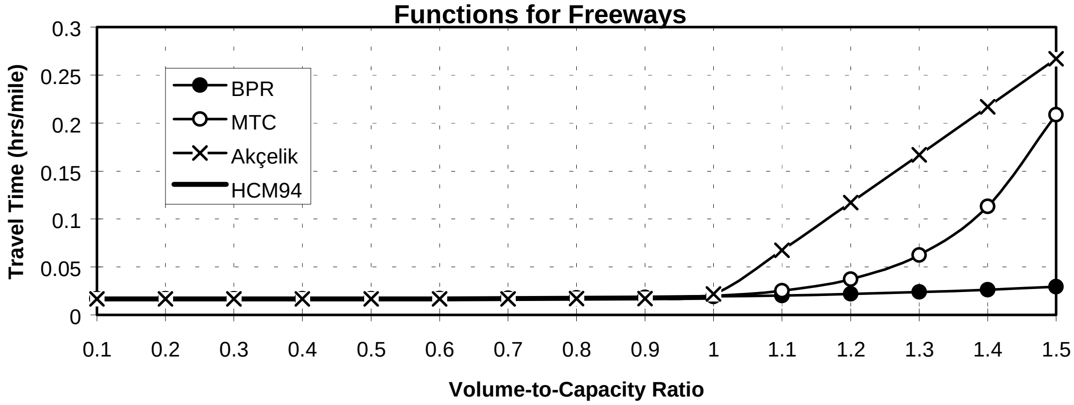


Figure 3
Compare AM Peak Hour and Peak Period VMT by Facility Type

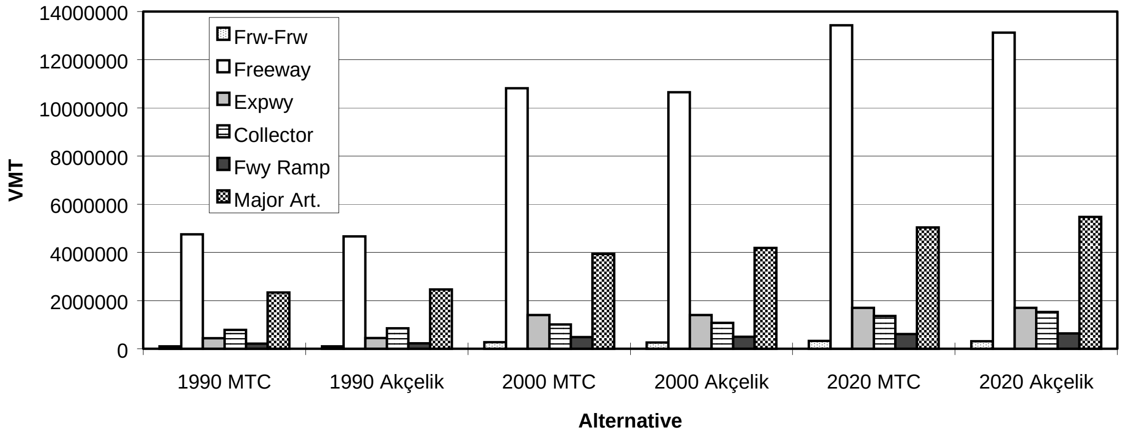


Figure 4
Compare AM Peak Hour and Peak Period Speeds by Facility Type

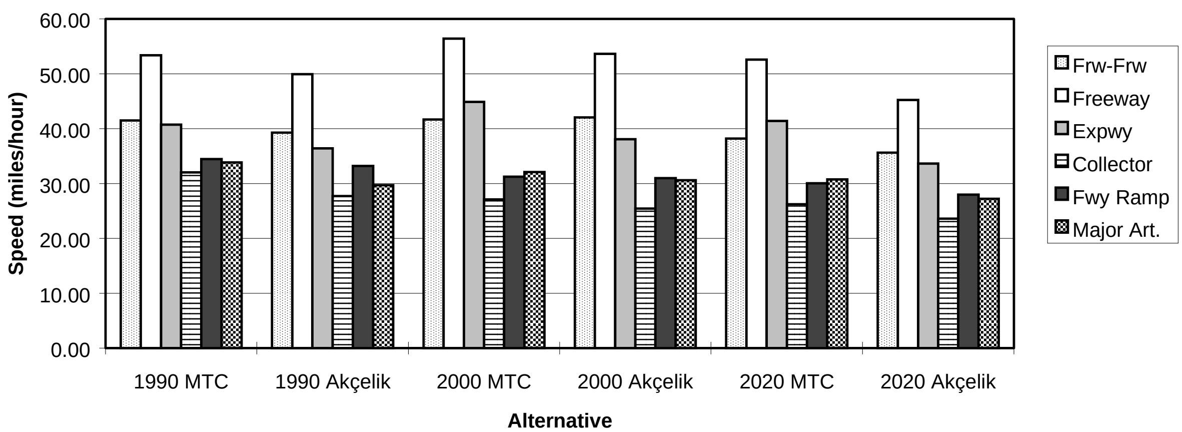


Figure 5
Compare Distribution of VMT by V/C Ratio

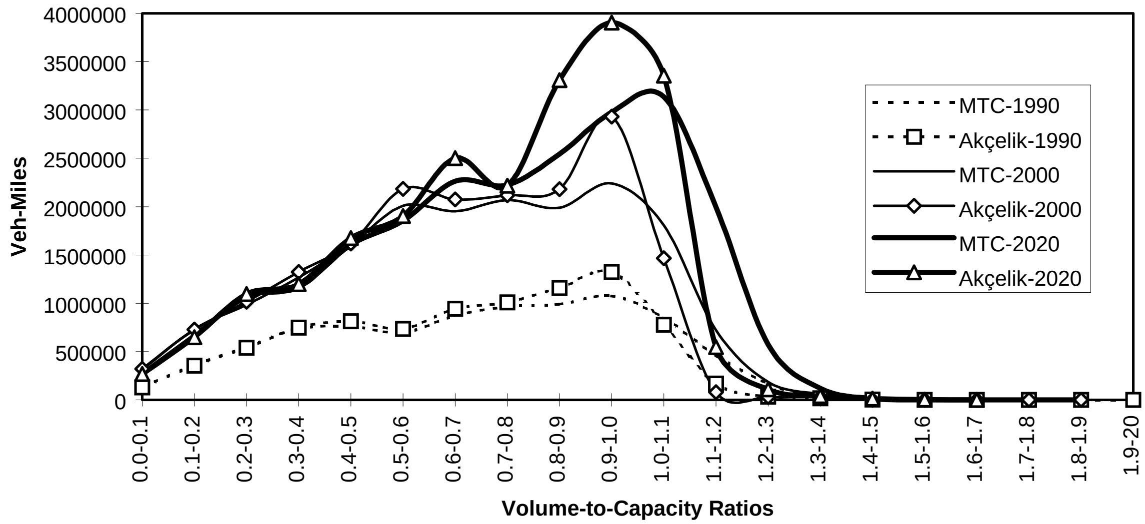


Figure 6
Compare Distribution of VHT by V/C Ratio

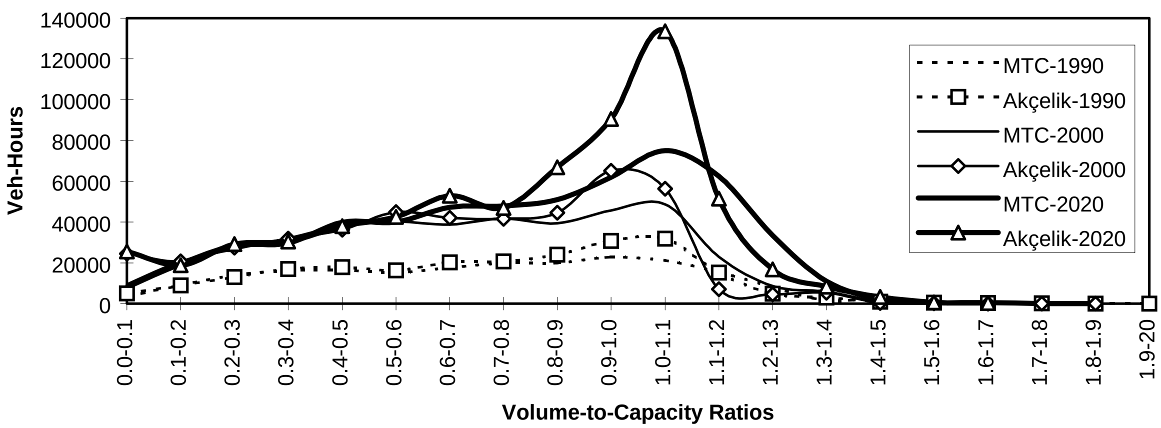


Figure 7
Compare Distribution of VMT by Speed - 1990 AM Peak Hour

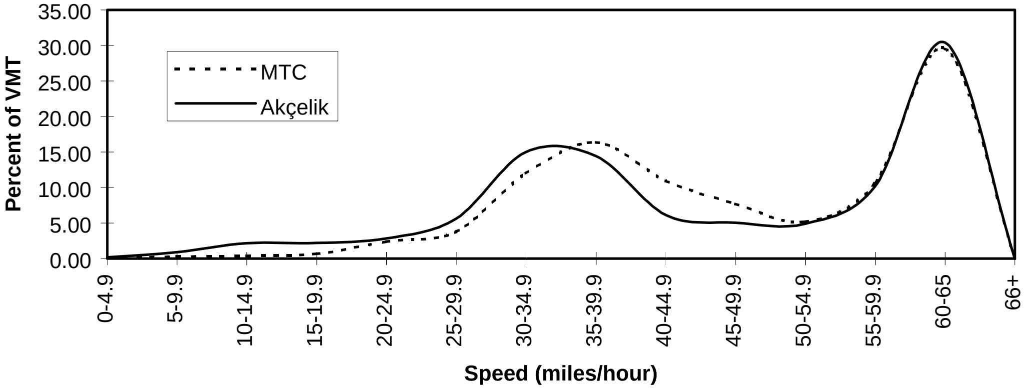


Figure 8
Compare Distribution of VMT by Speed - 2000 AM Peak Period

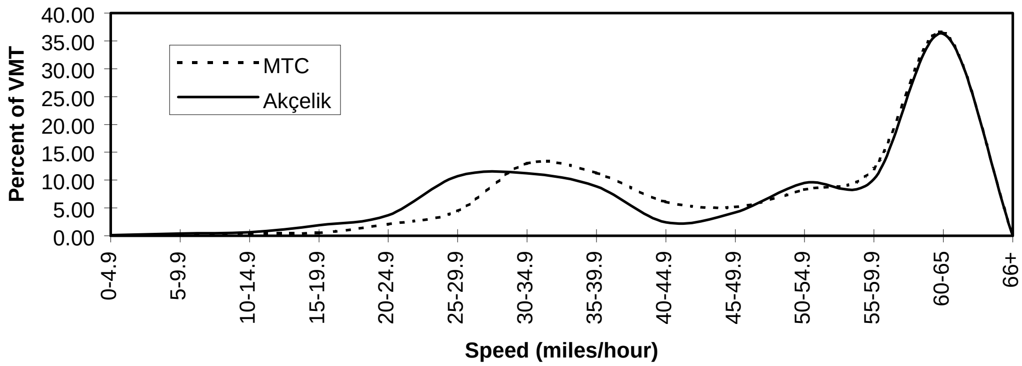
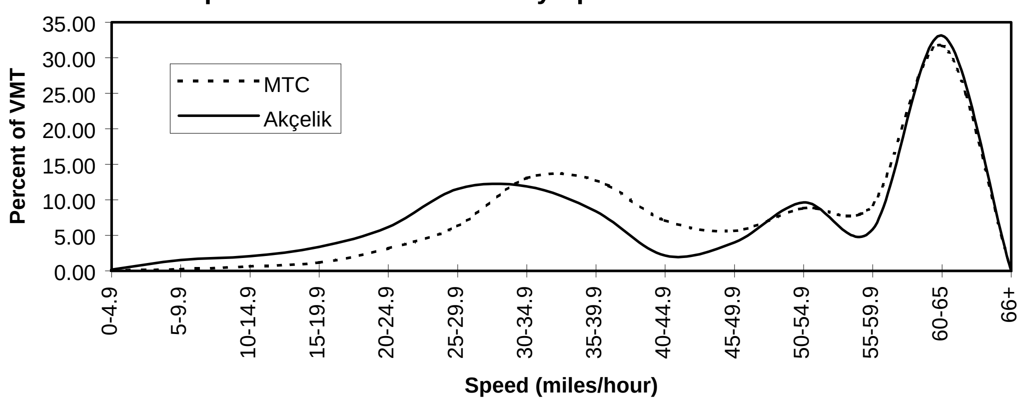


Figure 9
Compare Distribution of VMT by Speed - 2020 AM Peak Period



Calculating Delay on Congested Links Using a State Variable

Larry Blain, *Puget Sound Regional Council*

Abstract

Traffic flow on freeways exists in two states - uncongested (volumes below capacity) and congested. Delay functions used in assignments in regional modeling (such as the classic BPR function) calculate link travel times as monotonic increasing functions of the volume-to-capacity ratio. This works well for uncongested links, but the functions produce the slowest speeds only from volumes well in excess of capacity. In real life, link capacity under congested conditions is significantly below uncongested capacity. This paper describes an assignment algorithm which uses a state variable based on lane occupancy to identify congested links and select from a family of modified BPR functions which reduce capacity and constrain speeds to the lower branch of the volume-delay curve. The new functions, relating speed, volume, and lane occupancy, were derived from three years of 5-minute data gathered from the embedded loops of the Surveillance, Control, & Driver Information system operated on regional freeways by the Washington State Department of Transportation.

Problem Statement

The assignment procedures used in travel demand modeling incorporate one or more functions to calculate a congested travel time for each link based on that link's capacity and the assigned volume. In an attempt to replicate the behavior reported in the ITE Capacity Manual, these functions take many forms. The oldest function still in common use was published by the Bureau of Public Roads (BPR) in 1964:

$$T = T_0 * (1 + 0.15 * (V/C))^4$$

where

- T = link travel time
- T_0 = free-flow (zero-volume) link travel time
- V = assigned volume
- C = link capacity.

This and all other functions used to calculate congested travel times show a common weakness when used to model links with high congestion: very low speeds are associated only with volumes well in excess of capacity. What happens in reality is that volumes somewhat less than capacity occur with the flow in each of two much different states differentiated by vehicle spacing: widely spaced vehicles moving at a speed close to free-flow, and closely spaced vehicles moving at a much slower speed.

Fred Hall and others have written extensively about this phenomenon. His three dimensional diagram (Figure 1) shows clearly the relationship among flow, speed, and lane occupancy (the percent of the lane covered by vehicles - one measure of vehicle spacing). Virtually all delay functions replicate the region of uncongested operation.

No single function can yield two different speeds for the same less-than-capacity volume. The solution is to include lane occupancy either as a selector from among a family of delay functions or as a second independent variable.

Analysis

The Washington State Department of Transportation (WSDOT) has been collecting five-minute lane occupancy and traffic volume data with embedded loop counters on freeways in the central Puget Sound region for several years. These data are available on CDs - four per year.

When the data for one or more sites are plotted, the relationship between volume and lane occupancy becomes evident (Figure 2). Speed, flow, and lane occupancy are related through the average length of a vehicle:

(flow) x (average length) = (speed) x (lane occupancy).

The sharp lower edge of the plotted observations represents the free-flow state of constant speed, where flow and lane occupancy are linearly related by the average length of a vehicle. The speed limit at this site is 60mph. Assuming a speed of 65mph for this edge yields an average vehicle length of 17.5 feet - a reasonable value. This length then can be used to calculate the average speed corresponding to each of the observations.

When the volumes and calculated speeds are plotted, the familiar speed-flow diagram appears (Figure 3). The upper line, labeled “0.15", shows the standard BPR function defined at the beginning. It replicates the free-flow conditions quite well, but it is far away from the observations taken during periods of high congestion.

Solution

In order for the assignment process to converge, the delay functions must calculate speed as a monotonic decreasing function of volume. Therefore a *family* of functions must be used to cover the entire region of observations. The simplest family is created by varying the constant in the BPR function. Figure 3 shows the family which results from using 0.15, 0.50, 1.00, 2.00, 3.50, and 5.00. This family covers virtually all the observations which have sufficient volumes to be reliable.

An iterative procedure is used to determine the level of congestion on each link, and therefore the particular function which is appropriate for each link. At the beginning of the assignment process all links are given a congestion index of zero - the free-flow state, associated with the standard BPR function. After ten iterations of an equilibrium assignment the Volume/Capacity (V/C) ratio of each link is calculated. Any link with a V/C ratio greater than 1.1 is assigned a congestion index of one, associated with the BPR function using 0.50 for the constant. A circle on the graph shows the location of this upper limit for the V/C ratio.

After another ten-iteration equilibrium assignment, the V/C ratios are again recalculated. Again, any link with a congestion index of zero and a V/C ratio greater than 1.10 is assigned a congestion index of one and given the new delay function. Because the capacity of a congested link is effectively reduced, any link with a congestion index of one and a V/C ratio of *1.05* is assigned a congestion index of two, associated with the BPR function using 1.00 for the constant. This procedure is repeated three more times before the final assignment. Each time a link reaches the next state, the V/C ratio cutoff is smaller, and the next BPR function is used. The exact algorithm is given in the Appendix.

In the final assignment the speeds are calculated using the most recent BPR function. On congested links this produces the desired result of low speeds resulting from volumes somewhat lower than capacity. In a final calculation, lane occupancies are calculated from the final speeds and volumes. These lane occupancies can be used for producing congestion maps.

Results

So far this procedure has been used only on freeway links, since signals and queuing make arterials more difficult to analyze. When this procedure was applied to a three-hour PM peak period assignment, congested freeway links showed much lower speeds for the same volumes than their uncongested counterparts. For instance, I-90 into the Seattle CBD had a volume of 12,803, and out of the Seattle CBD had a volume of 12,277. Each direction had the same coded capacity (15,000/3hrs). But the speed into the city was 35.7mph, and the speed out of the city was 13.7mph. The lower speed for the more congested direction resulted from having a higher congestion index.

Conclusion

When used in a standard equilibrium assignment process, the algorithm described in this paper replicates the restricted flow and lower speeds which occur on freeways under highly congested conditions. As long as there are alternative routes available, the pressure to increase volumes above capacity will result in lower speeds and a diversion of trips instead.

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Gilchrist, Robert S., and Fred L. Hall. Three-Dimensional Relationships Among Traffic Flow Theory Variables. Transportation Research Record 1225. Pp. 99-108. 1989.

Appendix

Assignment Process

For each link:
    Congestion Index = 0

Ten-iteration equilibrium assignment using standard Delay Function
For each link:
    If (Volume > Congested Capacity) then (Congestion Index = Congestion Index + 1)
        *Note: Congested Capacity = (1.1 - 0.05 * Congestion Index) * Coded Capacity*

Ten-iteration equilibrium assignment using Delay Functions for the new Congestion Indices
For each link:
    If (Volume > Congested Capacity) then (Congestion Index = Congestion Index + 1)

Ten-iteration equilibrium assignment using Delay Functions for the new Congestion Indices
For each link:
    If (Volume > Congested Capacity) then (Congestion Index = Congestion Index + 1)

Ten-iteration equilibrium assignment using Delay Functions for the new Congestion Indices
For each link:
    If (Volume > Congested Capacity) then (Congestion Index = Congestion Index + 1)

Ten-iteration equilibrium assignment using Delay Functions for the new Congestion Indices
For each link:
    If (Volume > Congested Capacity) then (Congestion Index = Congestion Index + 1)

Final equilibrium assignment using the latest Delay Functions
For each link:
    Calculate Lane Occupancies using Speeds and Volumes

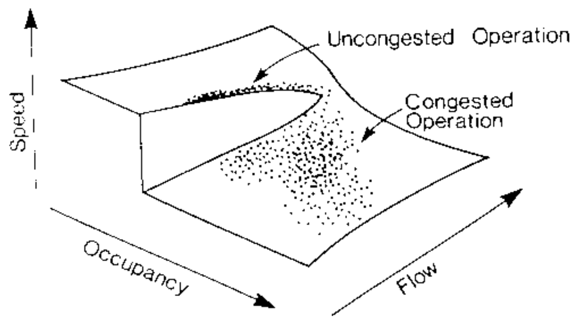


Figure 1

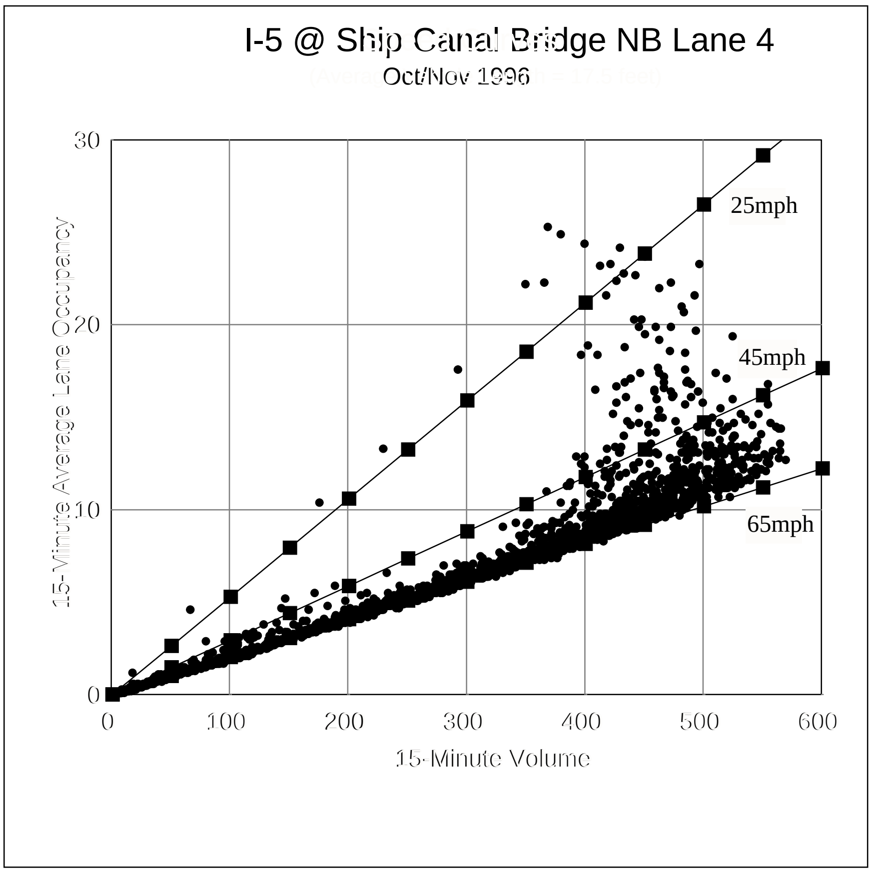
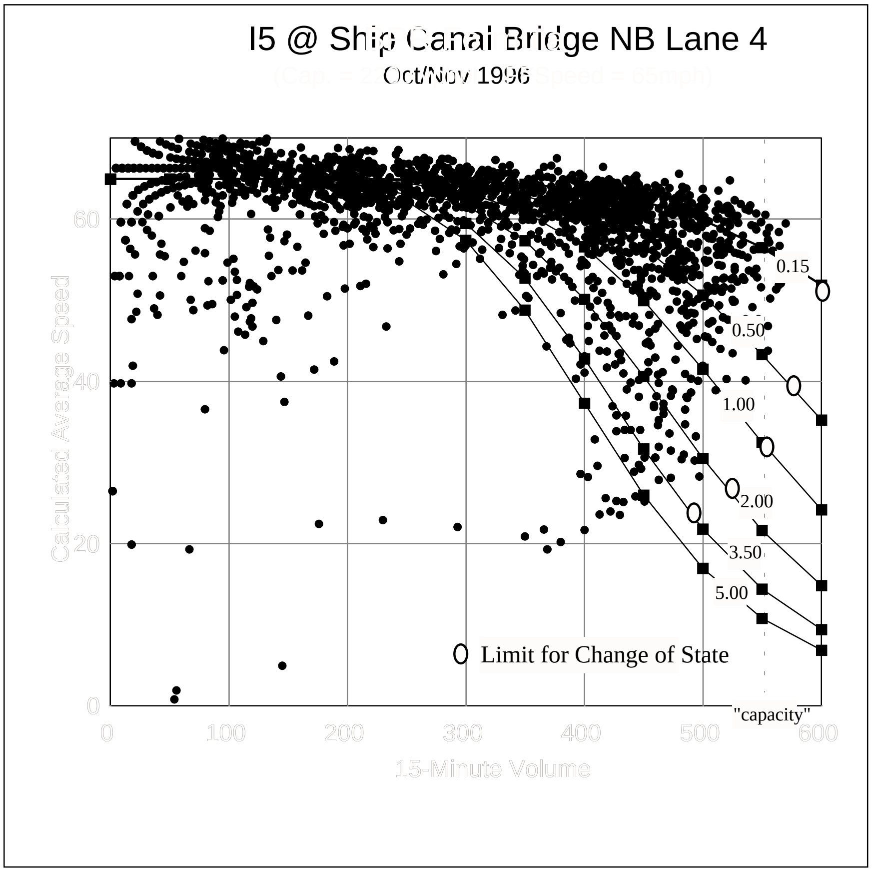


Figure 2


I5 @ Ship Canal Bridge NB Lane 4
Oct/Nov 1996
Calculated Average Speed
15-Minute Volume
0
20
40
60
100
200
300
400
500
600
0.15
0.50
1.00
2.00
3.50
5.00
Limit for Change of State
"capacity"

Using Travel Demand Models to Aid in Construction Staging and Detour Evaluation: The US-131 "S-Curve" in Grand Rapids, MI

Karen Faussett, Brad Winkler, and Paul Hershkowitz,
Michigan Department of Transportation

Abstract

In 1998, the Michigan Department of Transportation identified US-131 from Wealthy Street to Pearl Street, in Downtown Grand Rapids, as structurally deficient. This 1.5 mile (2.5 km) segment of US-131 is commonly known as "The S-Curve" and carries approximately 121,000 vehicles per day. "The S-Curve" is an elevated segment of freeway that contains four freeway interchanges, spans the Grand River, and is the main access to and from Downtown Grand Rapids. Final construction staging alternatives that were modeled and evaluated included total freeway closure, total directional closure (closing SB direction), and partial directional closure (2 lanes in each direction remained open). The presentation will describe how the Grand Valley Metro Council Travel Demand Model was used to help evaluate the maintenance of traffic impacts and detour alternatives, the impacts to the local roadway network by closing the freeway, and where highway system improvements would need to be made prior to the start of this project.

This presentation will first discuss the Maintenance of Traffic/Detour Evaluation process, and then use the above example to illustrate process points. We will also assess what worked well in the evaluation process (and what didn't), "do's and don'ts" regarding Maintenance of Traffic/Detour Evaluations, and methods for improving the process for the next time.

Using Model Integration to Meet the Needs of Multiple Departments within the Municipality of Anchorage

Gary Hendricks and Joe Savage, *KJS Associates, Inc*.;
and Jon Spring, *Municipality of Anchorage*

Abstract

The Municipality of Anchorage is developing a travel demand forecasting model to support local and regional transportation, transit and land use planning; traffic engineering; air quality conformance analysis; and highway performance monitoring. To meet these varied needs, the model has several integral components. It is tightly integrated with the Municipality's GIS system (ARC/Info), allowing transfer of data and model results between the GIS system and the model platform (TransCAD). The use of GIS also facilitates the development and analysis of the model's land use–transportation component, which allows land use and transportation planners to evaluate alternative land use patterns and transportation improvements, and their effects on each other. Integration with the State's Highway Performance Monitoring System (HPMS) allows two-way data transfer; data collected by the State, such as traffic counts, functional class and VMT are used for model validation, and model volumes are used by the HPMS for the State's reporting requirements.

The model includes several innovative modeling techniques to improve the representation of the travel patterns in the region, particularly the travel times used in the model processes and those reported by the model for integration with air quality modeling (using Mobile 5A). The trip generation model estimates total person trips, including non-motorized modes, and is done simultaneously with the time-of-day model. Trip distribution and assignment are done for four time periods—AM, PM, Midday and Nighttime—with times for the respective period fedback from assignment to distribution. The speeds output from the model are much more accurate by time period than with traditional diurnal factoring techniques, and trip distribution is improved by using appropriate times for each period rather than using a weighted average of congested and uncongested times for each purpose. The travel times are further improved with the use of node delay procedures for both signalized and unsignalized intersections. A level of service post processor assesses level-of-service by time period for links and intersections against Congestion Management System (CMS) standards and integrates the model with common traffic engineering procedures.

Forecasting Interurban Rail Trips: An Overview of Two Scenarios

Patrick J. Coleman, *KPMG LLP*

Abstract

Over the last few years, there have been numerous studies examining potential rail corridors in the 25-100 mile range. Proposed technologies for these corridors include both light and commuter rail. Since these corridors usually traverse more than one metropolitan area, a single regional forecasting model often will not adequately estimate patronage for the entire corridor. At the other extreme, these corridors are also too "short" for an "intercity" forecasting model. Since project resources usually do not allow for the development of an entirely new travel model, the approach must rely heavily on proven models and forecasting methods with existing, readily available data.

One approach is to estimate rail patronage by splitting the travel market into two segments according to trip characteristics. The "urban" market includes travel within metropolitan areas. Rail service in this market functions as a "premium" transit service between residential areas and major employment, shopping and other destinations in each urban area. Each region's existing travel model is applied to trips for this market. The "interurban" market includes travel between metropolitan areas and intermediate destinations. Rail service in this market functions like a traditional "interurban" service for exurban commuters, business travel, and other "discretionary" trips. A new model is developed for this market, incorporating elements of intercity and urban travel models. Thus, the approach is two-tiered and is geared to each market.

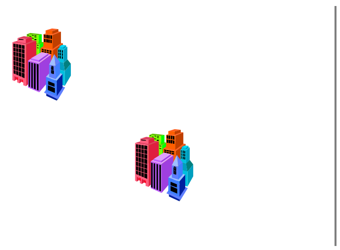
This paper presents an overview of how the approach was applied in two rail corridors: Philadelphia-Reading and Austin-San Antonio.

Over the last few years, there have been numerous studies examining potential rail corridors in the 25-100 mile range. Proposed technologies for these corridors include both light and commuter rail. Since these corridors usually traverse more than one metropolitan area, a single regional forecasting model often will not adequately estimate patronage for the entire corridor. At the other extreme, these corridors are also too "short" for an "intercity" forecasting model. Since project resources usually do not allow for the development of an entirely new travel model, the approach must rely heavily on proven models and forecasting methods with existing, readily available data.

An approach to forecasting potential rail trips in this type corridor is to split the travel market into two segments. Travel inside the corridor and inside a major metropolitan area can be considered the "urban" market. The definition of this market is constrained by the boundaries, trip characteristics, and capabilities of the regional forecasting model(s) in place. Travel inside the corridor but outside a major metropolitan area or from outside a metropolitan area to that area can be considered the "interurban" market. The interurban" market definition and assessment is limited by the regional models and existing secondary data sources used to create a new "sketch

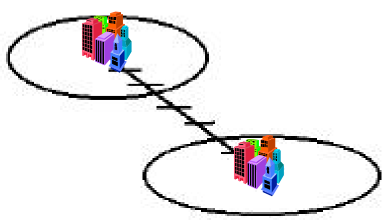
This idea of market segmentation can also be extended to the service the proposed rail line would be providing. In the urban market, travel is limited to the metropolitan area(s). Thus, the rail line functions as a "premium" transit service between residential, employment, shopping, and other areas. In the interurban market, the rail line functions like a traditional "interurban" service. The customers for the service include exurban commuters, business travelers, and other "discretionary" trips. Since a significant portion of the interurban market is non-work travel, this market can be very in size depending on the level of "off-peak" service the proposed rail line would operate.

This paper presents an overview of how the approach was applied in two different scenarios. Scenario "A" considers two urban areas whose regional model study areas border (in reality they overlap) each other. This scenario is the proposed Schuylkill Valley Metro corridor, which would connect Center City Philadelphia with downtown Reading.



SCENARIO A

Scenario "B" is a situation where two regional model study areas do not border each other and, in fact, have a "hole" in between them that is not covered by either regional model. This scenario is the proposed Austin-San Antonio commuter rail corridor, connecting those two cities and intermediate points.



SCENARIO B

Scenario A

Scenario A, a proposed rail corridor connecting Center City Philadelphia and Reading, Pennsylvania, was examined as part of the Schuylkill Valley Metro Feasibility Study. The corridor is approximately sixty miles in length and utilizes the existing Southeastern Pennsylvania Transportation Authority (SEPTA) R6 regional rail line as far as Norristown.

The following forecasting tools were used for each market segment:

- <u>The urban market</u>**.** *The Delaware Valley Regional Planning Commission (DVRPC) Travel Simulation Model* is run for trips within the Philadelphia metropolitan area. *The Berks County Travel Model* is run for trips within Reading and Berks County.

- <u>The interurban market</u>**.** A new model has been developed for trips *between* the Berks County and DVRPC regions. This model has been dubbed the *Interregional Model*.

Thus, an alternative that spans the entire corridor requires a simulation of each of three models to forecast each component of the travel market.

Overviews of the DVRPC and Berks County models are provided as well as a description of the *Interregional Model*. A description of the model flow follows.

A modified version of the 1510 zone *DVRPC Travel Simulation Model* was utilized. The process follows the common "four step" procedure with trip generation, trip distribution, modal split, and assignment steps. The process utilizes the TRANPLAN transportation planning software package and special programs developed by DVRPC. The trips between the DVRPC study area and Berks County have been removed since they are forecast using the new model. The DVRPC model is run for all trips within the DVRPC study area, external-external (X-X) trips, and those internal-external (I-X) trips that do not cross the Berks County cordon.

The *Berks County Travel Model*, maintained by the Berks County Planning Commission, has 808 zones and uses the MINUTP software platform. The Berks model uses a modified "four step" procedure which has been refined to include time of day modeling for highway assignments. *Trip generation* calculates the number of person trips produced by and attracted to each traffic zone by purpose. The trip ends are split into trips within Berks County (Internal-Internal or I-I) and trips going in and out of Berks County (Internal-External or I-X). *Trip distribution* calculates the number of trips between zone pairs. Composite impedances based on all available travel modes are used as the measure of zonal separation. *Mode choice* splits person trip by travel mode. Available modes include drive alone, carpool, walk to transit, and drive to transit. *Traffic assignment* assigns vehicle trips to the highway network by time period. Vehicle trips are split into time periods while being converted from production-attraction (P-A) to origin-destination (O-D) format.

For this analysis, however, a fixed trip distribution is assumed for the future year to ensure consistency with the *DVRPC Travel Simulation Model* and the *Interregional Model*. *The Berks County Travel Model* is run for trips within Berks County, external-external (X-X) trips, and those internal-external (I-X) trips that do not cross the Montgomery or Chester County cordons. These trips have been removed since they are forecast with the new model.

For the interurban market, KPMG developed the *Interregional Model* based on existing person trip and network data in both the *DVRPC Travel Simulation Model* and the *Berks County Travel Model*. A discussion of the model components follows, in terms of trip tables, travel times, modal choice, and assignment.

Trip Tables

The person trip tables for the *Interregional Model* were created from the post-distribution trip tables in the *Berks County Travel Model* by extracting productions and attractions at external stations at the Montgomery and Chester county lines. The new trip tables are transposed and, using data from the Berks County External Survey, factored to establish directionality. The percentage of surveyed trips that are Berks residents is assumed to be the percentage of trips traveling from Berks County to the DVRPC area. The seven Berks County trip purposes are collapsed to three for compatibility with the *DVRPC Travel Simulation Model*. Exhibit 1 lists the equivalency between the trip purposes.

The trip tables were then converted from MINUTP to TRANPLAN binary format using a specially written program. The trip attractions in the DVRPC internal-external (I-X) vehicle trip table are used to “distribute” the interregional trips in the DVRPC study area.

The Berks Traffic Analysis Zones (TAZ’s) are renumbered in the trip tables so as not to conflict shows the zonal equivalencies between models.

Travel Times

Travel times for all modes in the region (i.e. highway and transit) are a critical input to modal choice. Travel times are “read” from networks and summarized into discrete tables in files. The skim files are read directly by the modal choice program. The following discussion is a brief overview of the highway and transit travel time processes.

The *Interregional Model* uses the individual transit networks from the *DVRPC Travel Simulation Model* and the *Berks County Travel Model*. During transit pathbuilding, DVRPC pathbuilding parameters are used. When building paths from the Berks model, special MINUTP TRNPTH driver files were created that emulate DVRPC parameters.

During the skimming process, output skims from the Berks County model are converted to TRANPLAN binary format using a specially written program. Fare values are converted to link impedances and added to the travel times to emulate the DVRPC fare program. The zone numbers in the skim files are renumbered in the same manner as the trip tables (discussed in the Trip Tables section).

Travel times are “assembled” as impedance values from the external to the destination zone are added to each skim table such that the total impedance is represented. This is accomplished using SVMSKIM, a program developed for the Schuylkill Valley Metro Feasibility Study. For example, a trip from zone *I* in Berks County, crossing external *K*, to zone *J* in Montgomery County has the following impedance:

Total impedance = impedance from zone I to Berks external K +
impedance from Montgomery external K to zone J

Modal Choice

For modal choice, a set of “diversion curve” relationships were developed using the 1995 travel times and trips from the DVRPC portion of the Schuylkill Valley corridor. These new diversion curves are stratified by trip purpose (HBW, HBO, NHB) and destination (urban, non-urban). There are six total curves with the transit share on the y-axis and the difference in total impedance (e.g., transit impedance – auto impedance) on the x-axis. The curves were estimated using the standard TRANPLAN software.

Assignment

The post modal choice trip tables are "broken up" into the individual DVRPC and Berks County model zone systems and assigned to the DVRPC and Berks transit networks. Each transit trips is "broken" at the nearest external so that two sets of trip tables, a DVRPC set and a Berks set, are available for assignment. A specially written program converts the Berks County trip tables into MINUTP binary format.

Thus, the *Interregional Model* has the following characteristics:

- Urban models (DVRPC and Berks) run independently of the *Interregional Model*
- Trip Tables based on Berks internal-external (I-X) trips
- Travel times are "assembled" from urban model skim files
- Diversion curves based on the DVRPC model in corridor
- Post-modal choice trip tables are "broken up" into urban model components and assigned to their respective networks.

Scenario B

Scenario B, a proposed rail corridor connecting Austin and San Antonio, Texas, was examined as part of the Austin-San Antonio Commuter Rail Feasibility Study. The corridor is approximately one hundred miles in length and may utilize a portion of the Union Pacific (ex-MoPac) line.

The following forecasting tools were used for each market segment:

- <u>The urban market</u>. The *Capital Metro Model* is run for trips within the Austin urban area and the *San Antonio Multimodal Model* is run for trips within Bexar County, including the City of San Antonio.

- <u>The interurban travel market</u>. A new model has been developed for trips *between* Austin, San Antonio, and intermediate destinations such as San Marcos and New Braunfels. This model has been dubbed the *Interurban Model*.

Thus, an alternative that spans the entire corridor requires a simulation of each of three models to forecast each component of the travel market. Overviews of the *Capital Metro Model* and the *San Antonio Multimodal Model* are provided as well as a description of the *Interurban Model*. A description of the model flow follows.

The *Capital Metro Model* was developed for the Northwest/North Central Corridor AA/DEIS and has a 1992 base and 2020 future year. This model system was selected for Austin because of its mode choice model and availability. The area system covers the Austin Transportation Study (ATS) area and is consistent with TxDOT's 1985 model calibration. There are a total of 635 traffic serial zones (TSZ's) with 24 external stations. The model uses a incremental method to forecast transit trips which adjusts "synthetic" model results to match baseline observed travel patterns from the on-board survey.

The *San Antonio Multimodal Model* was developed by KPMG for use in the San Antonio/Bexar County MPO's current Metropolitan Transportation Plan Update. The newly recalibrated version (1995 base, 2020 forecast) of the model was used in this study. The area system for the model covers all of Bexar County. The 947 TAZ's are essentially those in the TxDOT's *San Antonio/Bexar County Travel Demand Model*.

Post-distribution *person* trip tables in TRANPLAN (production-attraction) format were provided by TxDOT for the years 1995 and 2020. The highway networks are based on TxDOT's 1995 and 2020 networks from the San Antonio/Bexar County Travel Demand Model. The Year 1995 and 2020 transit networks are based on networks developed for VIA Metropolitan Transit's Direct Generation Forecasting Model.

The modal choice model produces estimates of person trips by mode as well as auto vehicle trips by occupancy. The model is structured as a nested logit form which allows for sub-modal trade-offs to be fairly sensitive to service measures while lessening the impact on other less related sub-modes and allows for trade-offs between, for example, a local bus option with low speeds, moderate frequency, low fares, and short walking distances and premium service (such as commuter rail) with higher speeds, greater frequency, higher fares, and longer walking distances. Transit trips are assigned to the three transit paths: walk access to local transit, walk access to premium transit, and auto access to "best" transit.

For the interurban market, KPMG developed a "sketch planning" approach called the *Interurban Model*, which used some traditional travel demand forecasting procedures and was based on existing secondary data sources. The model development involved determining the rail "watershed" or market size and what share of the travel market each potential rail corridor can capture. Key data sources included the *IH 35 Corridor Origin-Destination Survey* and the *1990 Census Transportation Planning Package (CTPP)* data. A discussion of the model components follows, in terms of trip tables, travel times, modal choice, and assignment.

Trip Tables

CTPP Journey to Work (JTW) data from the Austin and San Antonio regions were used as the basis for a work trip table. Census tracts served as the zone structure for the *Interurban Model* outside the primary metropolitan areas (Austin and San Antonio). Inside the primary metropolitan areas traffic districts were used. Since the CTPP JTW data is at the county level outside the metropolitan areas, Census tract level population and employment data was used to allocate the county data to the tract level of detail. The newly reallocated JTW data was multiplied by 1.8 to convert the data to trips. This factor is a commonly used assumption in planning studies. Texas State Data Center and Woods and Poole population and employment estimates were used to grow the work trip table from 1990 to 1995 using the Fratar model. 1995 was the base year in order to utilize *IH 35 Corridor Origin-Destination Survey* results.

In addition to the CTPP-based work trip table, additional trips were added for Southwest Texas State University. The university provided work and school trips by zip code of origin. These trips were assigned the zone which best "fit" the zip code area. These trips were then added to the 1995 school trip tables.

Factors to relate work to non-work trip were developed for the 16 geographic zones in the *IH 35 Corridor Origin-Destination Survey*. Non-work trips include school (other than SWT), shopping, and recreation. The non-work trip factors will be applied to the 1995 work trip tables to produce a 1995 non-work trip table. This technique has been used by New Jersey Transit to develop non-work trip tables in commuter rail studies.

Travel Times

The highway network is a subset of the FHWA National Highway Planning Network (NHPN), Version 2.0. Highway links for the counties in the study area were extracted and centroid connectors added. The network was then created in TRANPLAN. Peak and off-peak speeds and capacities were assumed from the *San Antonio Multimodal Model*. These were used with the network to generate congested and free flow highway travel times for the mode choice process. The commuter rail and access links were coded using the standard TRANPLAN UNET process.

Mode Choice/Assignment

A "sketch planning" level mode choice model sensitive to commuter rail service developed by R.H. Pratt and Associates (1987) for the Virginia Railway Express (VRE, a commuter rail operation in suburban Washington, DC) for use in its initial planning stages was selected for the *Interurban Model*. The VRE model was reviewed and its constants adjusted to local conditions using the available time and cost sensitivity data from the *IH 35 Corridor Origin-Destination Survey*. The mode choice model was applied to the trip tables with travel times skimmed from the networks described above. The rail trips are then assigned to their respective networks.

Thus, the *Interurban Model* has the following characteristics:
- The *Capital Metro Model* and the *San Antonio Multimodal Model* are run independently
- The trip tables are based on CTPP JTW and survey data
- New highway and transit networks/skims were created
- The mode choice model transferred from outside the region

Summary

Exhibit 3 is a comparison of the major elements of Scenario A (*the Interregional Model*) and Scenario B (*the Interurban Model*).

Other Applications

KPMG is currently applying similar methodology in several ongoing studies. The Schuylkill Valley Metro Major Investment Major Investment Study/Draft Environmental Impact Statement essentially uses "Scenario A" with some further refinements. The Regional Commuting Patterns Study conducted for VIA Metopolitan Transit in San Antonio is using a "modified" Scenario B with only the *San Antonio Multimodal Model* as an urban model and a different *Interurban Model* mode choice procedure. The Northwestern New Jersey/Northeastern Pennsylvania Rail Passenger Study is also a modified "Scenario B" candidate. New Jersey *Travel Demand Model* (NJTDFM), developed by KPMG, is the urban model. Portions of the study area in Pennsylvania are grafted onto this model for work trips. A separate “Interurban” process is being developed for recreational trips.

Acknowledgements

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Austin Transportation Study
Capital Metropolitan Transportation Authority
VIA Metropolitan Transit
Carter and Burgess, Inc.

Exhibit 1: Trip Purpose Equivalency

Berks Trip Purposes	**DVRPC/Interregional Trip Purposes**
Homebased Work (HBW) School (SCH)	Homebased Work (HBW)
Homebased Shopping (HBS) Homebased Other (HBO)	Homebased Other (HBO)
Non-Homebased Non-Work (NWK) Non-Homebased At-Work (ATW) Journey to Work (JTW)	Non-Homebased (NHB)

Exhibit 2: Zonal Equivalencies

	DVRPC Model	**Berks Model**	**Interregional Model**
DVRPC Internals	1-1395	*n/a*	1-1395
DVRPC Externals	1396-1510	*n/a*	1396-1510
Berks Internals	*n/a*	1-673	1601-2274
Berks Externals	*n/a*	751-808	2376-2409

Exhibit 3. Scenario Comparison

	Scenario A	**Scenario B**
Urban Models	Independent (modified I-E trips)	Independent
Trip Tables	Adjusted I-E trips	CTPP JTW/survey-based
Networks	Uses urban networks	NHPN-based highway, new transit
Travel Times	Skims grafted from urban tables	New skims
Mode choice	Diversion curves based on urban model modal split	Transferred model

Why We Are Returning to the Traditional 4-Step Modeling Process

Cameron McGough, Ada Planning Association

Abstract

The early 1990’s (ISTEA) brought about new money for household travel surveys and related planning activities. Additionally, much hype about the advances in modeling techniques for trip chaining appeared to be on the front burner for conference papers. With all the hoopla and a major corridor study in the wings, Ada Planning Association took the plunge into converting form the traditional 4-step model process to the new trip chaining model.

Ada Planning Association is expanding its modeling boundaries into its western neighboring county, which provided an opportunity to assess where we are and where we want to be. After comparing the traditional 4-step and the trip chaining modeling process we were currently using, staff and modeling oversight committee chose to return to the traditional 4-step process.

This paper documents the reasons why the return to the “old” model. Several areas of comparison will be illustrated along with related information on the model expansion, the area characteristics, and the software conversion from TranPlan to TP+ and Viper (from the Urban Analysis Group).

Preparing for Growth: Accommodating Shifts in International Freight Flows

Lawrence Doxsey, *Standard & Poor's DRI*

Abstract

The next decade is expected to witness substantial growth in trade between the US and Latin America. The southeastern states are geographically well positioned to benefit from this growth as producers of exports, consumers of imports, and gateways for trade. Essential to effectively realizing and benefiting from this potential growth will be the planning and development of the infrastructure needed to move greater volumes of goods. In turn, detailed, accurate forecasts of the commodity and geographic composition of trade shifts can substantially enhance efforts to focus planning and development activities.

This paper describes the development of detailed forecasts of trade between the US and Latin America and presents summaries and highlights of the results. It goes on to illustrate use of the forecasts in "gap analysis", a process of screening for shortfalls of capacity relative to forecast volumes. This is the key analytic tool applied to reveal opportunities and risks, and to thereby guide port, highway and rail infrastructure investment planning. Gap analysis is facilitated by having forecasts unconstrained by existing or committed infrastructure capacity, a circumstance that for other applications would be a negative.

The forecast process begins by establishing a snapshot of recent history through an integration of private and public data on historical patterns of production, trade, and transportation. Identified are trade volumes by domestic port and foreign by commodity and mode, between ports and inland origins or destinations by commodity and mode, and between origins/destinations and foreign partners by commodity. Forecast of this same pattern of information are driven by detailed forecasts of foreign and domestic economic activity and by DRI's multilateral world trade model. Results of this work are now being used to set planning agendas and priorities within and among the southeastern states.

Statewide Traffic Prediction Model for Heavy Trucks

Elizabeth G. Jones, PhD, *University of Nebraska-Lincoln*;
and Stephen D. Andersen, *Nebraska Department of Roads*

Abstract

The rail industry in the U.S. is changing from servicing local shippers to point-to-point operations. Major railroads are abandoning or selling off branch lines as they move toward service to just a few large terminals. In Nebraska, it is anticipated that service may be limited to those grain elevators that can service “shuttle” trains (100 to 120 cars with power units) in 15 hours or less, including unloading and loading of all cars. Only approximately 10 such facilities throughout Nebraska are expected to develop. These service requirements will effectively eliminate co-loading of trains by several grain co-ops.

This change in the railroad structure affects the movement of freight within agriculture based states such as Nebraska. More agricultural products will be moving longer distances by truck, substantially impacting statewide road systems. The anticipated impacts include increased accidents involving trucks and accelerated deterioration of roads due to increased traffic by heavily loaded trucks. The current statewide planning methodologies cannot account for how changes in railroad structure and operations may impact a state’s road system.

This paper is reviews models that may be useful for predicting the traffic impact to a highway system from changes in railroad operations and the anticipated shift toward trucking traditional rail freight. Based on this comprehensive review, a conceptual methodology for a statewide freight transportation planning model that is useful for predicting modal shifts is presented.

The modeling process is developed so that it can be used in conjunction with current state-wide transportation modeling processes to predict the effects of structural and operational changes by the rail industry particularly within the State of Nebraska. The primary effect is expected to be an increase in the vehicle-miles traveled by trucks hauling agricultural products. Results of the identified modeling process can be used by transportation planners to more accurately identify where this increased truck traffic will occur. This information can then be used by transportation professionals to assess impacts on safety, design features, and road deterioration due to changes in truck traffic.

Logistical Analysis of Commodity Movements in the Portland Region

Erin E. Vaca and William R. Loudon, *Cambridge Systematics*; Richard Walker, *Portland METRO*; and Susie Lahsene, *Port of Portland*

Abstract

Portland Metro and the Port of Portland have jointly undertaken an effort to develop a model system to predict fright flows and the associated vehicle movements in the Portland region. To gain a better understanding of the complex process by which decisions about goods are moved in the region, an in-depth, structured set of interviews with motor carriers and major shippers in the Portland region are being conducted to support the model development. The planned model is intended to derive commercial vehicle movements from a database of base year and future commodity flows. The interviews have been fielded to provide guidance on typical logistical patterns and operating practices in order that these might be reflected in the model design.

The modeling of freight and goods has always been more complex than the modeling of passengers because their is far greater complexity in the characterization of what is being moved (its size, weight, perishability, etc.), there is less regularity and symmetry to the movement of goods and there is less independence between units being moved. But deregulation and continuing evolution of the freight movement industry have also changed many of the patterns and decision rules that have governed the industry in the past. The logistic survey in Portland was designed to gain a better understanding of the economics of goods movement in the Portland Region and how it relates to the use of truck trips to move the goods. For example, what determines whether a longhaul truckload travels first to a terminal rather than directly to the consignee upon entering the region?

The interviews are also being used as a forum for exploring the availability of electronic data that might support model development such as bills of lading and delivery route records. In addition, the interviews are being used to explore decision factors that impact parameters such as mode choice, shipment size and frequency, and delivery times. This paper/presentation will summarize what was learned about logistics and operational patterns but will also provide an assessment of the data collection method itself.

Developing a Freight Model Based Upon Commodity Flow Data

Richard E. Walker, *Portland METRO*; Susie Lahsene, *Port of Portland*;
and William R. Loudon and Erin Vaca, *Cambridge Systematics*

Abstract

The Portland, Oregon region is developing a truck flow simulation model. The model integrates a number of unique elements not often found in freight analytical tools.

A key prerequisite of the model is the development of a regionally based commodity flow estimate. Based upon economic indicators, the estimate predicts units of commodities by market segment (international / domestic), mode (truck, ship, barge, rail, air), and corridor (north, south, east, west). Focusing on truck transport, load factors are used to quantify truck flows from the commodity units.

The transport pattern within the region varies depending on the freight type. Upon entering the region, some goods are carried directly to market. Others require transport to a reloading site before the final distribution. After linking the generalized commodity / truck flows to regional points of entry and destination sites, a truck trip table can be synthesized that reflects the interaction between generation sites, reload centers, and port distribution locations.

Once the generalized transport patterns are defined, multiple data sources are used to more specifically allocate the truck trip ends throughout the regional landscape. Data includes 1) employment stratified by the Standard Industrial Classification codes from address based Tiger file records, 2) information regarding freight generation sites from an Intermodal Management System database, 3) Port of Portland records at key port of entry sites, and 4) count data at important freight shipment locations (reload sites, major generation sites). This information can be used with traditional trip rate relationships to proportion the established regional flows to specific sites.

Interviews are being conducted with freight transportation managers. The information derived from these sessions will be used to define operational characteristics (e.g., time of day patterns, vehicle load factors, number of shipments sent and received, commodity mixes at the site). This data is useful in refining the commodity / truck detailed flow patterns.

This paper defines the analytical process and illustrates the use of the miscellaneous data elements assembled to formulate the modeling tool.

MIS as a Community Test:
Is Indianapolis Ready for A Transit Revolution?

Kenneth S. Kinney, *Parsons Brinckerhoff Quade & Douglas, Inc*.; and
Lori Miser, *Indianapolis Metropolitan Planning Organization*

Abstract

The issues of urban sprawl and related transportation concerns have become widely perceived as among the top problems in the Indianapolis metropolitan region. Especially in the Northeast Corridor, which stretches about 25 miles from downtown Indianapolis into Hamilton County, among the 20 fastest growing counties in the country, congestion has far surpassed acceptable levels, and for most transportation markets there is no alternative to the automobile. In addition, the public and elected officials have been disappointed by some recent studies that suggested major expansion of existing highways, a strategy that is increasingly perceived as infeasible—as well as ineffective.

Improving public transit would seem to be a logical strategy to address those concerns in the corridor. However, the perception (and reality) of transit in the region makes such an approach problematic. The reality is that Indianapolis provides one of the poorest levels of bus service among comparable cities in the U.S. The perception, especially among choice riders, is that the system really does not provide a reasonable choice. The result is that many in the community believe that it (a major transit investment) *won't* happen here because it *can't* happen here.

Still, there are some community leaders who feel that the time is right to test that belief. They believe that the atmosphere is right for such a test: severe congestion in the corridor, doubts about highway-expansion-only approaches, public ownership of a rail corridor that traverses the heart of the corridor—and a federal grant for an MIS. Thus, one of the most important unstated objectives of the Northeast Corridor MIS—called conNECTions—is to determine if the region is willing and able to look seriously at major transit investments.

ConNECTions (NECT standing for Northeast Corridor Transportation) includes several noteworthy features, including being the first true "multimodal" MIS in Indiana, the first serious looks at major transit investments in Indianapolis, regionally focused, and with an extensive public involvement program. Alternatives being considered include freeway and arterial expansion, light rail and commuter rail, busways and express bus service, HOV facilities, express lanes and park-and-ride strategies. In addition, INDOT is strongly backing a serious consideration of congestion pricing—another "first" for the study. The MIS started in April of 1998 and will be completed by the end of 1999.

Indianapolis is not known for its transit system, but that could be changing. The Indianapolis Metropolitan Planning Organization (MPO), in conjunction with the Indiana Department of Transportation, Hamilton County, the cities of Indianapolis, Carmel and Noblesville, the town of Fishers, the Office of Mobility Management and the Indianapolis Public Transportation

Corporation, is currently conducting a major investment study (MIS) in the Indianapolis region. This is the first time that a true multi-modal MIS has been conducted in the state of Indiana. The MIS is taking a serious look at both transit and highway options, and we are headed toward what could truly be a transit revolution in central Indiana.

Currently we have:

- service and ridership levels that are lower than cities of comparable size and demographics,
- a system that is predominantly oriented to the central business district, while dispersed development is occurring rapidly throughout the region, and
- a system that lacks a true identity as well as a positive image in the minds of choice riders.

However, the system is fairly cost-effective, given the resources that are devoted to it. The current focus is on the transit dependent, and the system does a decent job of serving that market.

Even with those factors in mind, we see a revolution on the horizon. Clues are coming from all directions (geographically and figuratively):

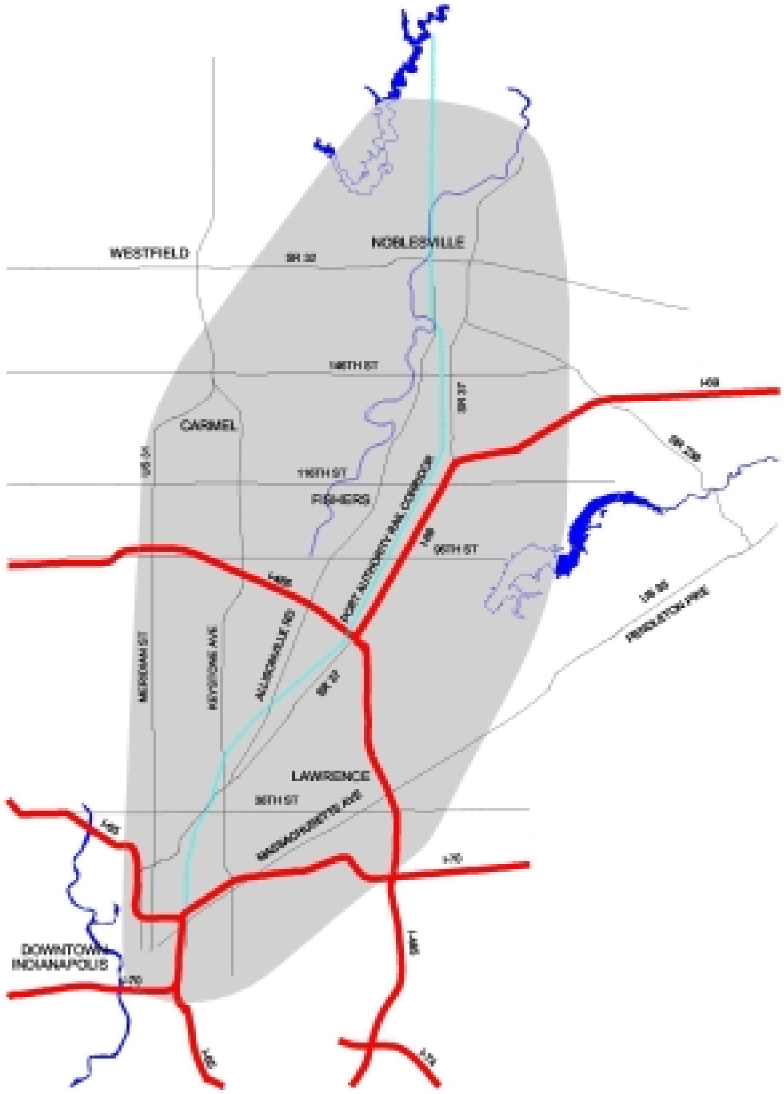
- traffic congestion is increasing to unacceptable levels,
- employers are having trouble finding employees because of a very low unemployment rate
- there is a growing awareness of urban sprawl, which is currently the number one concern with the recently formed Central Indiana Regional Citizens League (CIRCL), and
- many are concerned where current trends will lead if we do not take a proactive position now.

Forecasts for 1990-2020 growth for the metropolitan planning area show that population is projected to increase 27 percent, households 38 percent and employment 44 percent. In contrast, the MPO travel forecast model projections for 1990 to 2020 show a 48 percent increase in person trips, a 69 percent increase in vehicle miles of travel (VMT) and a 77 percent increase in vehicle hours of travel (VHT).

The main area of concern is located to the northeast of the Indianapolis central business district and includes the fastest growing area in the state and one of the fastest in the country (see map, next page). The traffic problem in this corridor is obvious, so this is the obvious place to conduct a true multi-modal MIS to try to improve congestion problems and increase mobility options.

The increases in VHT's and VMT's threaten the quality of life in central Indiana. They also indicate that the traditional approach of simply adding lanes to highways will not be enough to handle growth of this magnitude. The preliminary MIS analysis points to significant capacity expansion on our major freeways *if* we consider roadway expansion as the *only* option to solve the problem. If we consider transit and the impact it could have, the future scenario could change. For the first time in Indianapolis, transit is considered to have a serious chance to make a difference.

NORTHEAST CORRIDOR STUDY AREA MAP



How did Indianapolis get to this point? With traffic congestion that is low by national standards but growing and projected to be major by local standards, with a bus system that serves only Indianapolis/Marion County (with one small exception) and is focused on the transit dependent, what has happened to move these issues to the forefront? You might say the stars became aligned at the opportune time.

A study of I-69 and State Road 37 in the northeast corridor conducted in the “traditional” way—design for a particular level of service, project the traffic and derive the number of lanes needed—generated significant interest and concern when the recommendations noted a need for

12-14 lanes to accommodate traffic to meet level of service D. That recommendation would have resulted in the taking of many homes and businesses, and the public called for an examination of other ways to solve the congestion problem.

In addition, a freight railroad, which cuts diagonally through the northeast corridor was abandoned and purchased by a consortium composed of the City of Noblesville and the Town of Fishers: the Hoosier Heritage Port Authority. Although it is often a mistake to consider a rail corridor simply because it is available (and therefore "cheap," both financially and politically), this rail line is perfectly positioned to help address the traffic problem and increase mobility options in the area.

Even though the rail corridor is perfectly positioned and the Port Authority has recommended using the corridor for passenger rail service, the MIS is taking a broader look at the transportation needs and how they can best be met. The alternatives being examined for the corridor include roadway and highway options, improvements to and expansions of the bus system, a busway on the rail corridor, light rail and commuter rail options. Many other "lower cost" options are also being considered, including travel demand management techniques, ramp metering, ITS strategies, signal timing improvements and other options that could have a positive impact on traffic operations.

The specific transit options being considered include:
- the addition of express bus service from Hamilton County (where no bus service currently exists) into Marion County and the CBD,
- express service from Hamilton County to the CBD using an exclusive busway,
- commuter rail service between Noblesville and downtown Indianapolis,
- express light rail service between Noblesville and downtown Indianapolis, and
- commuter rail between Noblesville and downtown Indianapolis plus express light rail transit service from a transit center located at I-465 to the CBD.

Improvements to the existing bus system will be critical to the success of any strategy. Current service is weak for most routes, and routes labeled as "express" really are not; "express" routes that include two trips inbound in the morning and two trips outbound in the afternoon, and which have travel times only comparable to local service, are hardly likely to attract choice riders to the system.

In comparing the Indianapolis system to other similar cities such as Columbus, OH, Milwaukee, WI, Portland, OR, and the Twin Cities of Minnesota (see table next page), the statistics show that Indianapolis lags far behind in ridership, though not in some cost and efficiency categories.

On the positive side, the public is becoming much more interested in the transportation issue. It is becoming a stronger partner in the planning process, as evidenced by the public participation in the MIS and the participation and interest in the Central Indiana Transportation and Land Use Vision Plan.

Transit Systems: Indianapolis in Context	Indianapolis	Columbus	Milwaukee	Portland	Twin Cities
Population of Urbanized Area (million)	0.91	0.95	1.23	1.17	2.08
Annual Trips (million)	10.9	17.6	56.5	64.5	61.1
Annual Operating Expenses (million)	$24.1	$51.1	$89.5	$145.2	$125.9
Annual Fare Revenue (million)	$7.8	$10.7	$32.8	$31.8	$43.7
Annual Subsidy (million)	$16.3	$23.4	$56.7	$113.3	$82.2
Farebox Recovery Rate	32%	21%	37%	22%	35%
Subsidy Per Ride	$1.50	$1.33	$1.00	$1.76	$1.35
Annual Subsidy Per Resident	$17.83	$24.76	$46.09	$96.67	$39.51
Annual Trips Per Resident	12.0	18.5	45.9	55.1	29.4

Source: Federal Transit Administration

The public involvement component of the MIS is extensive and unprecedented in Indianapolis. The study was given a theme: *con**NECT**ions*, with "NECT" standing for Northeast Corridor Transportation and a tag line: *linking our regions opportunities*.

The components that make up the public involvement program include: a citizens advisory committee (CAC) which meets monthly, newsletters, brochures, a web site (www.indygov.org/connections) a toll free interactive voice response system (1-877-NEC-LINK), focus groups, telephone surveys, media campaign, public service announcements, group appearances and public meetings.

Although the MIS started before the completion of the vision plan, that community-based process helped build support for a serious look at transit. It also demonstrated that this support was regional in scale—indeed, transportation is the first regional issue being formally addressed. The vision plan was commissioned by a local private endowment and facilitated by the Central Indiana Regional Citizens League (CIRCL). A 60-plus-member steering committee helped to guide the process, and numerous public forums throughout the nine-county area helped to shape the principles of the plan.
The plan's Vision Statement is: *The future mobility needs of all Central Indiana's citizens will be met through a variety of environmentally sound choices, solutions, and policies and at*

publicly acceptable costs.

The vision plan is being discussed and evaluated by the public, elected officials and interested organizations and groups. The intended use of the vision plan is to:

- raise awareness of the connection between how we use land and the costs of meeting the future mobility needs of our citizens,
- challenge citizens of the region to think and act together *now* for the sake of our *future* mobility and community quality of life, and
- offer a range of sensible mobility and land use planning options for consideration in local as well as cross-community decision-making.

The vision plan recommends the following strategies to achieve the projected outcomes for transportation:

- light rail transit,
- park-ride lots,
- comprehensive regional bus service—local and express,
- a cross-community transit plan, and
- stable funding mechanisms, such as sales or gas taxes in addition to user fees.

Land use objectives include:

- higher intensity zoning along transit corridors,
- mixed-use, compact development options,
- infill/brownfields development in urban areas,
- preserving open spaces and farmland through land trusts,
- paths, lanes and sidewalk options in new developments, and
- a cross-community plan with model zoning ordinances.

Another critical piece of the overall strategic planning context is the Central Indiana Regional Transit Service Plan, now being completed by the MPO. This effort will result in the development of a long-range (25-year) transit plan for the entire nine-county region. In terms of support for short-term transit investment in the northeast corridor, the plan and the process of creating it, will help answer the frequently asked question: Of course the northeast is the top priority, but when will service reach other parts of the region? Answering that question will help build support for the MIS's preferred alternative on a broader geographic base.

Logically, the planning sequence would have been: vision plan, transit service plan, MIS. But despite the actual sequencing, the overall logic of rational planning for a revolutionary approach to transportation's impact on the regional quality of life is becoming clear. In addition—and this is the critical lesson from our yet-to-be-completed experience in Indianapolis—sometimes logical purity must yield to short-term opportunity, that rare alignment of the stars. In our case those stars included ISTEA and TEA 21, a newly purchased rail line, a questioning of traditional highway expansion, and the sudden emergence of uncontrollable congestion on the regional radar screen.

The Role of Travel Demand Forecasts in the Resort Corridor Major Investment Study: The Las Vegas Experience

Adiyana Sharag-Eldin, *Regional Transportation Commission*; and
Dawn McKinstry, *Parsons Brinckerhoff Quade & Douglas, Inc.*

Abstract

The Las Vegas Resort Corridor is the geographic and economic center of the nation's fastest-growing metropolitan area. This unprecedented growth has placed huge demands on the existing transportation infrastructure, and raised concerns about future mobility needs in the area. Given this, the Regional Transportation Commission of Clark County (RTC) selected Parsons Brinckerhoff Quade & Douglas, Inc., to perform a Major Investment Study (MIS) in the Resort Corridor of Las Vegas, Nevada.

The Major Investment Study process provides a systematic approach to identify and assess a full range of transportation alternatives. One of the major elements needed in assessing the alternatives is travel demand forecasting. The results of the travel forecasting efforts are used in many elements of the MIS process.

This papers focuses on the role that the travel demand forecasts played in the MIS. Twelve alternatives were evaluated, including a No Build (which consisted of the Regional Transportation Plan and the Short Range Transit Plan) and eleven other combinations of bus, street and highway, and fixed guideway improvements. These alternatives were analyzed using the region's interim travel demand model set. This model is a traditional four-step model with three mode choice models to reflect the unique travel populations in Las Vegas. These mode choice models reflect trip-making choices, not only for the residents, but also for the visitors and air passengers to the Las Vegas region.

In addition, the paper presents the model results, and compares the transit foreasts and rail ridership to other cities. The results show that a rail line is not necessarily a gamble in Las Vegas.

Introduction

What do you think of when you hear Las Vegas? Glitz? Glamour? Gambling? Growth? Most likely not growth but that is certainly what is happening in the Las Vegas Valley. This rapid growth has placed a huge demand on the existing transportation infrastructure and is one of the reasons a Major Investment Study (MIS) was undertaken.

The MIS process provides a systematic approach to identify and assess a full range of transportation alternatives. One of the major tools needed in assessing the alternatives is a travel demand model. The results of the travel forecasting effort are used in many facets of the MIS process. This paper relates the Las Vegas experience and the role that the travel demand forecasts played in the MIS.

The paper is divided into six sections. It starts with some history and background of Las Vegas, narrows the focus into the Resort Corridor, describes the Resort Corridor Major Investment Study, reviews the travel forecasting process, touches on the MIS elements that require input for the travel forecasting task, and concluded with some findings and recommendations.

Las Vegas Background

Las Vegas, Spanish for "the meadows" is located in the in the Las Vegas Valley on the eastern edge of the Mojave desert, about 30 miles west of the Colorado River. The Valley is approximately 40 miles long and 15 miles wide, range in elevation from 1,500 feet to 3,000 feet. The City was founded in 1905 as an outcome of the completion of the main railway, linking Southern California with Salt Lake City. The City was governed as part of Lincoln County until 1906 when it became the county seat for the newly established Clark County. The city's growth started in the 1930s as a result of the Hoover Dam construction. Thousands of jobless workers and their families flocked to the Las Vegas area during the Great Depression with hopes of working on the Hoover Dam.

In 1931, the state law legalized gambling. This regulation gave cities and counties the authority to collect taxes and issue gambling licenses. Until now, the gaming industry remained the dominant force in the metropolitan economy. The electricity supply from Hoover Dam became a major factor in the creation of resort hotel and casino billboards - what make the skylights of Las Vegas today.

Divorce laws were liberalized in the State of Nevada, making residency easier to attain. The divorce papers could be attained after six weeks of residency. In these short-term, most of the residents stayed at the ranches, which were forerunners of the sprawling Strip hotels.
As the numbers of hotel rooms in Las Vegas grew during the early 1950's, city leaders began to focus their attention on a new market: conventions. By bringing in large groups of people for business purposes, hotel operators could increase bookings during the slow part of the week and slack periods during the year.

For the last ten years, the hotel rooms in Las Vegas has increased over 50% (Table 1). And the expansion has not ended. In 1980 Las Vegas had about 46,000 hotel and motel rooms with 12 million visitors. A decade later, in 1990, the city featured nearly 74,000 hotel and motel rooms and welcomed almost 21 million visitors. By the end of 1999 the hotel and motel rooms in Las Vegas will reach 120,000 with over 30 million visitors annually.

Starting in the 1980s, a period of unprecedented growth began. Annual population in Clark County increased nearly 8 percent, doubling the population between 1980 – 1995. Contributing to the population growth was a 6 percent annual increase in hotel rooms and a 7 percent annual increase in jobs from 1990 through 1995 (Table 2). The economic growth has attracted both blue collar and professional workers to start new lives in the Las Vegas region.

Housing development is another barometer of the region's remarkable growth. The location in the southwest Sunbelt region attracts retirees to relocate in Las Vegas. Housing prices are relatively inexpensive because of the abundance of land in the desert area and the large pool of skilled labor. In 1990, there were 302,000 dwelling units in the valley; almost doubling within a decade, approximately 245,000 new dwelling units will be added by the end of this century. Interstate 15 and U.S. 95 played a key role in encouraging the sprawl in the Valley. The sprawl has placed tremendous demands on the existing transportation infrastructure, raising community concerns about existing and future mobility needs.

Travel demand forecasts show that mobility demands will far exceed the capacity of the existing and current planned transportation systems to be implemented between now and the year 2020. Recognizing the regional significance of the existing and future mobility needs, the Regional Transportation Commission of Clark County (RTC) initiated a Major Investment Study (MIS). The purpose of the MIS was to identify and evaluate a variety of alternative transportation strategies for the Resort Corridor.

Las Vegas Resort Corridor

The Las Vegas Resort Corridor is the geographic and economic center of the Las Vegas Valley. The predominant land uses in the Resort Corridor are casinos, hotels, motels, and other gaming based businesses. The Resort Corridor also contains a number of major medical facilities, an international airport, the University of Nevada – Las Vegas, residential housing and the primary offices of federal, state, and local government.

In 1995 the Resort Corridor contained half of all jobs within the region. By 2020, the total number of jobs in the Corridor will increase by 84 percent over 1995 levels. The percentage of Resort Corridor jobs compared to the region will decrease as the Resort Corridor reaches build-out, however the absolute number of jobs continues to increase within the Corridor (Table 3).

The land use and demographic information for 1995, indicate the population in the Las Vegas region was approximately 950,000, of that, just 11 percent (108,000) lived in the Resort Corridor. In 2020, the total number of people in the Resort Corridor will increase slightly to about 124,000 people, or 5 percent of the population in the Valley. Although the Resort Corridor's share of the region's population is dropping from 11 percent to 5 percent it is still gaining population and not yet totally built out.

Given that today there are twice as many jobs in the Resort Corridor as there are people, it is obvious that the majority of people employed in the Resort Corridor must live outside its boundaries and, therefore, must commute into the Resort Corridor to work. In the future, as the trend worsens and the residential areas within the Resort Corridor reach build-out, the home-based work trips will constitute a substantial portion of the daily travel demand in the Resort Corridor.

In addition to the imbalance of population and employment some other contributing factors to the travel deficiencies in the Resort Corridor are:

- Las Vegas is a driving oriented place; most of the trips are dominated by private automobile. Parking is abundant and property access is oriented to the arterial streets. Pedestrian convenience is considered secondary to vehicle access.
- Vehicle occupancy is low (an average of 1.3 persons per trip), especially for home-based work trips (approximately 1.15 persons per vehicle).
- Currently, less than 3 percent of person trips within the Resort Corridor were made by transit. To keep pace the bus service will have to increase 4.5 times over the 1995 levels to provide for the estimated year 2020 travel demand. This means the bus service would need to operate with two-minute headways. The road capacity can not accommodate the number of buses required to serve the area, especially along the Strip.

The Resort Corridor Major Investment Study (MIS)

The RTC recognizes that the travel demand will far exceed the capacities of the transportation system as currently planned. In 1995, the RTC conducted a Major Investment Study (MIS) for the Resort Corridor. The objective of the MIS was to identify and evaluate alternative strategies to accommodate the mobility demands within the Resort Corridor and prepare recommendations for a preferred action plan.

In this study, the RTC identified the following summary of the findings of need:

- Between 1995 to 2020 the full implementation of the Region Transportation Plan (RTP) will increase roadway capacity by 27 percent. During this period, demand for vehicle travel will increase approximately 54 percent.
- The RTC will have to build an equivalent of 20 east-west and 18 north-south arterial lanes of roadways in the Resort Corridor in addition to the roadway projects already programmed in the Regional Transportation Plan (RTP) to provide for mobility.
- The RTP will consume all existing roadway rights-of-way and will complete the roadway infrastructure improvement program for the Resort Corridor. If new roadway construction, or widening of existing travel way is to occur beyond those identified in the RTP, additional right-of-way will have to be acquired.
- Regional vehicle travel, especially residential trips to and from work in the Resort Corridor contribute significantly to the travel demands placed on the Resort Corridor's roadways.
- Regional utilization of public bus transit (Citizens Area Transit or CAT) increased by 167 percent between 1993 to 1997. Attempting to solve the roadway congestion conditions in the Resort Corridor solely by expanding the ridership on CAT will be virtually impossible unless substantial infrastructure improvements are also implemented to increase the ability of buses to operate on the roadways.
- Meeting the mobility demands within the Resort Corridor will require the establishment of a multi-modal, fully integrated set of transportation solutions.
- Travel volumes, land use densities, and concentrations of employment warrant the consideration of establishing a higher order of public transit that operates in a separate right-of-way.

- Programs directed at reducing the amount of travel in private vehicles and encouraging the use of public transit within the Resort Corridor and between the Corridor and the remainder of the community are needed.

Based on the findings of need, the Regional Transportation Commission adopted a draft Statement of Purpose and Need to guide this Major Investment Study. The statement is:

> "The purpose of the Resort Corridor Major Investment Study is to identify and evaluate alternative programs and/or infrastructure improvements that can accommodate increased trip-making demands that will occur by 2015 such that levels of congestion and mobility opportunities do not deteriorate below the conditions experienced in 1995. Further, it is the stated intent of the [MIS] participants that the mobility opportunities for residents and visitors to Las Vegas be enhanced."

Maintaining existing levels of mobility over the next 20 years in the Resort Corridor will require a combination of transportation improvements and changes in travel behavior. Alternative strategies for meeting the mobility challenges were identified in the following Transportation Improvement Elements (TIEs):

- Transportation System Management (TSM) and Transportation Demand Management (TDM) element.
- Fixed Guideway Element (Exhibit A).
- Enhanced Bus System
- Street and Highway Improvements

These elements were combined into eleven alternatives, plus a No Build for analysis and review in the MIS. The mobility impacts of each of the twelve alternatives were analyzed using the regional travel demand model. However, the regional forecasting model had to be updated with a mode choice element prior to the evaluation of these alternatives. Information about the interim model update can be obtained from two technical reports; *Interim Resident Nested Logit Mode Choice Model Specifications & Model Calibration, and Non-Resident Visitor Model Estimation & Calibration* prepared for the RTC by Parsons Brinckerhoff in September 1997.

Travel Forecast Process

Beginning in 1995, the RTC conducted travel surveys to collect information on current travel behavior and travel patterns for the Las Vegas area for use in the model update. These surveys included:

- Household Survey - 24 hour trip diaries from approximately 1800 households.
- Airport Travel Survey - 900 respondents completed the survey.
- Hotel Visitor Survey - participated by 14 hotels.
- On Board Transit Survey - a total of 3000 respondents completed the survey.

The survey data were used to develop calibration target values and to calibrate the interim mode choice models. The interim mode choice models will be replaced with models developed from the travel survey data in 1999.

The RTC modeling process follows the typical four-step process: trip generation, trip distribution, mode choice and trip assignment. The RTC utilizes the TRANPLAN travel forecasting package as their modeling software. What is unique about the RTC process is the implementation of three mode choice model sets. These three sets represent the different types of trip makers in the region; residents, visitors, and air passengers.

The Interim Resident model is comprised of four trip purposes. They are:

- Home-Based Work
- Home-Based School
- Home-Based Non Work
- Non Home Based

The Non-Resident Visitor model includes the following six trip purposes:

- Hotel-Based Business
- Hotel-Based Convention
- Hotel-Based Gaming-Related
- Hotel-Based Other
- Non Hotel-Based Gaming-Related
- Non Hotel-Based Other

The Air Passenger model has one trip purpose, it accounts for those visitors that have one end of their trip at the airport.

The final step is the trip assignment phase. The RTC travel demand model uses TRANPLAN's equilibrium highway assignment module to obtain highway assignments and the standard transit assignment and loading procedures for the transit elements.

Other MIS Elements Need Travel Demand Forecasting Information

In addition to the typical outputs of highway assignments and number of transit boardings, the travel demand forecasts play a major role in other facets of a MIS. Both the environmental and the engineering disciples require input from the travel demand forecasting effort of a MIS.

The environmental discipline utilizes the travel demand forecasts in several areas. The traffic forecasts are necessary input into the traffic circulation element, and noise analysis. The air quality analysis utilizes travel forecasts for the "hot spot" analysis and the vehicle miles traveled (VMT) and vehicle hours traveled (VHT) are utilized in the microscale and mesoscale analysis. The energy analysis and the noise analysis both require the number of rail transit vehicles. The energy analysis also needs the bus transit and rail transit VMT.

The engineering discipline utilizes the peak load points out of the transit assignments to determine, the number of rail vehicles needed, and the size of the train sets by time of day. Once the size of the trains are determined the platform lengths can be developed. The transit VMT and

VHT are also utilized in the Operating and Maintenance Cost calculations and the number of vehicles is used in the Capital Cost calculations.

Findings and Recommendations

The conclusion of this study is a set of recommendations and findings. The following recommendations are described for each of the Transportation Improvement Elements established early on in the study.

TSM and TDM Element Recommendations:

- Promote modes of transportation that will move more people via fewer vehicles.
- Construct elevated pedestrian crosswalks at major intersections along Las Vegas Boulevard.
- Implement an Intelligent Transportation System (ITS) to improve traffic flow on the freeway.
- Expand regional trip reduction programs and promote high-occupancy vehicle (HOV) trips.

Enhanced Bus System Recommendations:

- Increase number of Citizens Area Transit (***CAT***) buses.
- Decrease headways during peak hours.
- Add peak hour and shift-change express bus services.
- Enhance current ***CAT*** facilities and services.
- Build park-and-ride lots at the periphery of the congestion zones.

Fixed Guideway Element Recommendations:

- Establish an advanced transit system that accommodates both residents and tourists.
- Design routes that serve population and business areas and connect to ***CAT*** bus routes.
- Build a mostly-elevated system to avoid costs associated with tunneling underground or problems with excessive right-of-way issues.
- Choose a technology that will carry 20,000 people each hour on each track.

Street and Highway Improvements Recommendations:

- Implement eight new roadway improvement projects in or near the Resort Corridor.
- Construct a frontage access road along the Eastside of I-15.

In addition to the recommendations for TIE, several travel forecasting related findings from the MIS are of interest. They include the following:

- The fixed guideway element provides an overall travel time saving with less cost.
- If the fixed guideway had existed in 1995 it would have served approximately 43,000 daily rail riders.
- By year 2020 it is estimated that the system will carry over 300,000 daily rail riders.

A question that is often asked, is how does Las Vegas rail ridership compare to other systems in the county? To answer that question a travel forecast model run was made using the Las Vegas 1995 demographics and highway system, and what is envisioned as the 2020 transit system, including over 36 miles of rail. The results showed Las Vegas compared favorably to other systems even if only the Las Vegas resident trips were included. Adding both residents and visitors, it was estimated to have over 8500 daily rail boardings per system mile, twice what the Buffalo-NFTA system carried, and over three times what The San Diego Trolley carried. A comparison of 1995 Daily Boardings for selected systems is shown in Table 4. The estimated annual boardings per system mile for Las Vegas would be among the highest in the country. So perhaps a rail system in Las Vegas is not a gamble!

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Table 1
Las Vegas Hotel Rooms, Hotel Rooms Occupancy Rates and Annual Growth

Year	Hotel Rooms	Occupancy Rates	Annual Rate of Growth
1989	67,391	89.8%	
1990	73,730	89.1%	9.4%
1991	76,879	85.2%	4.3%
1992	76,523	88.8%	--
1993	86,053	92.6%	12.5%
1994	88,560	92.6%	2.9%
1995	90,046	91.4%	1.7%
1996	99,072	93.4%	10.0%
1997	105,347	90.3%	6.3%
1998	112,674	90.1%	7.0%
1999	120,000	90.4%	6.5%

Source: Salomon Smith Barney

Table 2
Clark County Population and Employment

Year	Population	Employment
1970*	273,288	111,200
1980*	463,087	217,500
1990*	741,459	374,167
1995*	1,040,688	481,425
2000**	1,269,600	609,400

*Source: * Regional Transportation Commission, Regional Vehicle Miles of Travel (VMT) Estimates and Projections 1990 – 2020, 1996.*

*** Regional Transportation Commission, Planning Variables Documentation, 1998.*

Table 3
Population and Employment Inside and Outside the Resort Corridor

Location	1995		2020	
	Population	Employment	Population	Employment
Within Resort Corridor	108,000 (11%)	230,000 (48%)	124,000 (5%)	423,000 (37%)
Outside Resort Corridor	887,000 (89%)	247,000 (52%)	2,282,000 (95%)	732,000 (63%)
Total Region	950,000	477,000	2,406,000	1,155,000

Source: Regional Transportation Commission, Planning Variables Documentation, 1998.

Table 4
Comparison of 1995 Daily Boardings for Select Systems

City/Agency	Directional Route Miles	Number of Stations	Annual Boardings in (000's)	Annual Boardings per System Mile	Daily Boardings in (000's)	Daily Boardings per System Mile
Sacramento-LRT	36.2	28	7,063.7	390,260	23.5	1,298
San Diego-The Trolley	41.5	35	15,624.4	752,983	52.1	2,511
San Jose-SCCTD	39	33	5,659.3	290,221	18.9	969
Denver--RTD	10.6	15	4,054.4	764,981	13.5	2,547
St. Louis-Bi-State	34	18	12,488.2	734,600	41.6	2,447
Cleveland-RTA	26.7	29	4,445.0	332,959	14.8	1,109
Portland-Tri-Met	30.2	27	7,779.5	515,199	25.9	1,715
Pittsburgh-PAT	38.1	13	7,996.1	419,743	26.7	1,402
Buffalo-NFTA	12.4	14	7,598.1	1,225,500	25.3	4,081
Long Beach--LACMTA	44	22	15,000.0	681,818	50.0	2,273
Las Vegas--Residents	36.8	26	13,050.0	709,239	43.5	2,364
Las Vegas--Visitors	36.8	26	34,377.6	1,868,348	114.3	6,212
Las Vegas--Total	**36.8**	**26**	**47,427.6**	**2,577,587**	**157.8**	**8,576**
Bally's Monorail	2	2	6,000.0	6,000,000	20.0	20,000

Source: The National Transit Data Base, 1998.
Regional Transportation Commission, Resort Corridor Major Investment Study, Final Evaluation Report, October 1997.

Dallas Area Rapid Transit Southeast Corridor Needs Assessment: MIS Preview or Duplication of Effort?

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Abstract

Prior to initiating a major investment study (MIS) for the Southeast Corridor of the Dallas Area Rapid Transit (DART) service area, the agency conducted a needs assessment. The purpose of the needs assessment was to identify travel patterns, identify transportation issues and deficiencies, develop a MIS community involvement plan, and prepare a preliminary statement of purpose and need for the MIS for the Southeast Corridor. The Southeast Corridor is identified in the region's long range plan and DART's Transit System Plan as a priority corridor for transportation improvements. Both the MPO's Mobility 2020 Plan and DART's System Plan recommended light rail as the appropriate technology for this corridor. The Mobility 2020 Plan recommends further evaluation of the engineering and environmental implications of this alternative as well as other modes and alignments connecting the Dallas central business district to the southeastern portion of Dallas County. The MIS for the Southeast Corridor was begun in September, 1998.

Upon completion of the needs assessment, a basic question arose: was the Needs Assessment process redundant given the upcoming MIS process or did it provide information useful for the MIS? The results are mixed. The Needs Assessment provided a solid basis for starting the MIS process for the corridor. DART staff has a good sense of the issues in the community involvement for the MIS through the Needs Assessment process. Considerable time and effort, however, will be spent in the MIS in evaluating other modes and addressing concerns of the communities in the corridor regarding why DART is considering technologies other than light rail. Given the anticipated changes in the regulations for planning and conducting a MIS under TEA-21, DART's experience with its needs assessments and MIS studies points to the need for a reassessment of MIS planning requirements, particularly for extensions of existing fixed guideway systems.

Southwest San Antonio (Kelly AFB) Mobility Study

Clay R. Smith, P.E., *Texas Department of Transportation*

Abstract

Many Air Force bases nationwide, including Kelly AFB in San Antonio, Texas, were selected for either phase-out or privatization. The 1995 Defense Base Closure and Realignment Commission (BRAC) determined the Air Force has excess capacity and infrastructure in their depot system, and realignment of the San Air Logistics Center (ALC) would permit improved utilization of the remaining depots and reduce Department of Defense operating costs. The BRAC recommended the consolidation of workloads to other DOD depots or to private sector commercial activities.

The City of San Antonio created the Greater Kelly Development Corporation (GKDC) to lead the communities' efforts to reuse and re-energize the many resources and develop the Master Plan for Kelly. The GKDC's planning and implementation efforts are aimed at developing a multimodal distribution center.

Surface Transportation needs to preserve and enhance accessibility to, from and within Kelly are imperative. The Metropolitan Planning Organization (MPO), TxDOT, the City of San Antonio, Bexar County, the GKDC, and other stakeholder representatives comprised an oversite group, the Kelly Transportation Task Force (KTTF), to access the transportation infrastructure needs outside of the current Kelly Air Force Base boundaries. The challenge of the study focused on a base that originally had restricted base access for security reasons to a free unrestricted movement of goods to the inside of Kelly. The primary goal of the mobility study was to maximize opportunities for commuters and freight to interchange the new Kelly facility without compromising the quality of life in the surrounding neighborhoods, schools and small business. The identified improvements both short and long range, included transportation management policies, pedestrian amenities, widening existing arterials, and construction new of arterials and interchanges. These improvements were identified by area residents, school districts, church representatives, local officials and TxDOT through a series of public meetings.

Large intermodal shipping companies are seeking the warehouse space, staging areas and strategic locations at Kelly to increase their global position in the market. Assets such as an all-weather runway capable of landing C-5s, the Union Pacific intermodal rail terminal and a network of external highways around Kelly AFB make the future inland port concept a viable option. The GKDC's continued efforts to lure good companies through privatization of a intermodal site and with the KTTF Study now complete, efforts are underway to implement the identified transportation needs and seek the appropriate funding for the short term and long range projects.

As a matter of background, San Antonio is blessed with a good transportation system made up of four interstate highways and a series of railroad lines and two loops around the city. It has a population of 1.4 million (8th in the U.S.) and was recently recognized as having the best highways in the United States. San Antonio has the top tourist attraction in Texas, the Alamo, which is one of five historic missions built by the Spanish missionaries to bring Christianity, culture and farming to the Indians. The City has six military bases (four Air Force and two Army).

Kelly Air Force Base is San Antonio's largest employer with over 19,000 employees. However, a major change took place in 1995. Many Air Force Bases nationwide, including Kelly AFB in San Antonio, Texas, were selected for either phase-out or privatization. The 1995 Defense Base Closure and Realignment Commission (BRAC) determined the Air Force has excess capacity and infrastructure in their depot system and realignment of the Air Logistics Center (ALC) would permit improved utilization of the remaining depots and reduce Department of Defense (DOD) operating costs. The BRAC recommended the consolidation of workloads to other DOD depots or to private sector commercial activities. Kelly AFB is the largest base closure of its kind. Although, it has the potential to become one of the best international logistics and intermodal distribution centers in the nation because of its geographical location.

Kelly has over 1,900 acres of land and facilities, a modern airport with maximum capacity runways, capable of landing C-5's, an adjacent Union Pacific railroad yard, in immediate proximity to IH 35 (a north-south corridor) and IH 10/US 90 (an east-west corridor) freeways.

San Antonio's location midway between Florida and California and its proximity to Mexico and Central America make it a logical transshipment point and a transportation HUB in Texas and even the United States. In fact, 80 percent of Mexico's trade with the US and Canada travels through Texas; and of this, 75 percent of this trade is by rail or truck through San Antonio. It is estimated, the total US-Mexico trade through San Antonio will be $285 billion by the year 2015.

In an effort to meet these base closures and loss of job challenges, the City of San Antonio created the Greater Kelly Development Corporation (GKDC) to lead the communities' efforts to reuse and re-energize the many resources and develop the master plan for Kelly. The GKDC's planning and implementation efforts are aimed at:

- Developing a multimodal distribution center.
- Identify land use.
- Identify transportation needs inside Kelly.

The GKDC also was charged with developing an internal transportation circulation plan for freight, rail and air. This included new access locations or closure of some existing gates, if necessary. This plan identified:

- $25 million on base street improvements.
- $43.6 million in parking and pedestrian improvements.
- $17 million in rail improvements.

Presently, large intermodal companies are seeking warehouse space, staging areas and strategic locations at Kelly to increase their global position in the market.

The GKDC has been successful in attracting flagship tenants to the base such as:

- Boeing – 800 to 1,000 jobs
- EG&G
- Pratt and Whitney – 2,000 jobs
- Rail Car Texas
- GE industrial Systems
- MQSI Inspections
- Ryder Integrated Logistics

In addition to the new tenants locating internally on Kelly AFB, there are many companies locating externally to Kelly AFB. Momentum at Kelly is high for job creation and conversion of the military base into the city's largest industrial park and multimodal distribution facility. The goal for Kelly is to create 21,000 to 26,000 new jobs, which would offset the loss of jobs because of the realignment effort.

Concurrent to the GKDC study, The San Antonio Bexar County Metropolitan Planning Organization (MPO) sponsored a Southwest San Antonio (Kelly AFB) mobility study ($250,000) with funding from the FHWA, TxDOT, Bexar County, and the City of San Antonio. The study oversite group was called the Kelly Transportation Task Force which was chaired by TxDOT and consisted of 10 local and state agencies. The objectives of the study was to:

- Identify deficiencies in the existing highway and transportation systems outside Kelly.
- Determine future travel demand in the study area.
- Develop a short and long range transportation and circulation plan for the southwest San Antonio area.
- Identify, evaluate and rank candidate highway and transit improvement projects.
- Maximize the ability to get commuters and freight into and out of the redeveloped Kelly facility without compromising the quality of life of the surrounding neighborhoods, schools and small businesses.

Like all military installations, Kelly AFB was designed more for physical security than for good transportation access into the base. This provides a challenge.

Through the study, three public meetings were held in neighborhood schools with more than 300 people attending. Improvements and concerns were identified by area residents, school districts, church representatives, local officials and TxDOT that were used in developing the final plan. Improvements included transportation management policies, pedestrian amenities, widening existing arterials, and construction of new arterials and interchanges. Concerns varied from environmental contamination in the community linked to Kelly AFB, and trucks being routed through residential neighborhoods. The design of the public meetings provided for small group discussions and comments. We believe the public involvement process provided the community support for the improvements identified in the study.

The Kelly Mobility Study identified three geographic access systems:

1. Northwest Access System provides access from US 90 to 36th Street and General McMullen on the north side of the base.

   - Improvements include upgrading the US 90 and 36th Street interchange and widening 36th Street to six lanes.

   - Constructing a northern loop along Thompson and/or Weir Streets.

2. The Northeast Access System provides both employee and truck traffic access to the intermodal center while keeping 18-wheeler traffic out of established neighborhoods and schools. It is intended to separate trucks from residential areas and have them routed to commercial and industrial area. Improvements include:

   - Western connections from General McMullen (Spur 371) to US 90 and US 90 to General McMullen that do not exist today.

   - Widen General Hudnell from four to six lanes.

   - Reconstruct the interchange at General McMullen, Frio City Road and Cupples Road which is also known as Kelly Crossroads.

3. The Southern Access System is composed of the extension of the Spur 371, South to SH 16. This southern section is known as the Kelly Parkway.

The Kelly Parkway is envisioned to be a limited controlled access, four lane divided principal arterial linking SH 16 and IH 35 to Kelly AFB. The Kelly Parkway will serve as a primary route for NAFTA related traffic wanting to access Kelly, its flight line and the intermodal distribution center.

Most of the highway improvements identified in these three access systems involve TxDOT with right of way acquisition being the responsibility of the City. A San Antonio delegation composed of the Chamber of Commerce, elected officials and the City of San Antonio has appeared before the Texas Transportation Commission on three occasions. The delegation has requested preliminary engineering authority and project funding from the Commission and have only received authority for the local TxDOT district to perform preliminary engineering.

The Texas Transportation Commission approves all NHS projects for funding in the entire State and each project competes statewide with cities, like Houston and Dallas. Each project follows three levels of authority approved by the Commission.

- Long Range Program (LRP) projects – develop right way needs, environmental studies, route studies.

- Priority 2 Status – purchases right of way and plan preparation.

- Priority 1 Status – project is funded.

The Texas Transportation Commission identifies these projects in an annual document called the Unified Transportation Program (UTP).
The LRP projects: currently identified in the FY 1999 UTP are:

- Spur 371 (General Hudnell) – from US 90 to End-South is planned to be widened to six lanes and westerly access to US 90 - $50.6 million

- Spur 371 (Kelly Parkway) – from General Hudnell to IH 410 – is planned to be a four lane divided without any access - $91.8 million

- US 90 at Loop 13 – Reconstruction Intersection - $9.88 million

- US 90 from 36th Street to IH 35 – construct new frontage roads - $25.69 million

Priority 2 Projects:

- US 90 at Cupples – construct turnaround

Priority 1 Projects with Demonstration Funds (TEA 21):

- US 90 at 36th Street – reconstruct intersection - $1.46 million

- 36th Street – US 90 to Growden - $3.51 million

Priority 1 Projects with MPO STP Funds:

- Weir Loop – Growden to General McMullen – reconstruct roadway - $3.87million

- Callaghan Road – extension - $7 million

In a recently completed study between San Antonio and Austin, a commuter rail was identified as another mode of transportation within this corridor in the future. The southern transfer station was sited in the study to be at Kelly. Also, Kelly would sever as a maintenance facility for the rail cars.

In summary, the cooperation from the City of San Antonio, Bexar County, Kelly AFB, the MPO, citizens and TxDOT has been imperative. The GKDC is working enthusiastically to attract new business and increase job opportunities in and around Kelly. The success in attracting the new businesses, I believe, is partially due to the transportation plan to provide improved access to Kelly on a short term and long term basis. The transportation development is a dynamic process and work is well underway for transportation improvements to support the Kelly AFB realignment by TxDOT.

The study's success can be attributed to excellent public involvement. Small break out sessions and language interpreters at the public meetings provided for an informal atmosphere. A forum for the citizens, to express their concerns and having City and State officials present to listen, was important to the community.

There are still challenges and a lot of work yet to be done. The most important is the ability to communicate with the GKDC concerning changes internally and externally to the original study. Changes internally or externally from the original study could severely hinder transportation or development opportunities.

San Antonio has learned from its experiences with the BRAC and Kelly AFB. The military will probably be facing more realignments in the near future. Our Congressional, State and local officials are already studying the privatization possibility at Brooks Air Force Base, which barely missed realignment last time. But, if San Antonio is targeted for more base closures or realignments in the future, the City has a model of how to overcome a bad situation.

Airports in Urban Areas and their Influence on Noise Effects from Multimodal Transportation Projects

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Parsons Brinckerhoff Quade & Douglas, Inc.

Abstract

The East-West Multimodal Corridor in Miami-Dade County, Florida is a unique case study in the area of noise analysis. Noise effects from the project arise not only from increased traffic after implementing transit and roadway improvements, but also from frequent aircraft movements as the roadway corridor is located within the flight path of one of the nation's busiest airports. Federal Noise Regulations are unambiguous for the analysis of noise from highways and transit systems, under unimodal conditions, but appear to be somewhat vague for multimodal conditions. In Miami, the addition of aircraft noise to the overall noise conditions presented unique challenges in noise impact assessment and noise abatement analysis. Consideration must be given not only to the existing and the future traffic, train, and aircraft noise levels, but also to the analysis period, peak periods of operations for all modes, frequency of train passages, day/night noise levels (Ldn) for aircraft operations, and location of noise receptor sites relative to flight paths.

The East-West Multimodal Corridor includes highway improvements to SR 836 (The Dolphin Expressway), and a new 12-mile rail transit system within the roadway. The SR 836 corridor runs through residential and commercial/industrial land uses. To assess noise impacts, the Federal Highway Administration (FHWA)/Florida Department of Transportation (FDOT) guidelines and the Federal Transit Administration (FTA) guidelines were applied separately to highway sites and train/highway sites, respectively. Each agency has very different criteria with respect to impact assessment - the FHWA compares future noise levels to an absolute maximum level (Noise Abatement Criteria) and the FTA compares future project noise levels to existing/ambient noise levels. What's unusual is how aircraft noise levels are taken into consideration.

At four highway-only sites, noise impacts were identified following methods specified in the FHWA/FDOT criteria. Future traffic and aircraft noise levels were all above the FDOT "approach" level of 65 dBA. But, peak periods of aircraft noise occur at roughly the same time as peak highway noise levels along the project corridor. Abatement of traffic noise with noise barriers is not expected provide the required noise reduction because the barrier acoustical effectiveness would be compromised by the high level of aircraft noise. Of the 15 highway/rail transit sites, only one site was considered an impact site as determined by the FTA criteria. With a noise barrier constructed along the transit guide-way, train noise can be effectively reduced to satisfy the FTA's allowable increase in noise exposure. One could argue that if highway noise barriers are ineffective for aircraft noise, then transit noise barriers are ineffective also. But, with transit, the FTA is most concerned with off-peak period noise levels as they affect residential land uses involving sleep. Considerations such as frequency of train passages and aircraft overflights during off-peak hours weighed heavily in favor of recommending a noise barrier.

Using SMITE to Estimate Induced Travel and Evaluate Urban Highway Expansion

Patrick DeCorla-Souza, AICP, *Federal Highway Administration*; and Harry Cohen

Abstract

This paper demonstrates an application of the sketch-planning model called "Spreadsheet Model for Induced Travel Estimation" (SMITE) to estimate induced travel and evaluate highway capacity expansion in an urban setting. SMITE is based on the principles of economic analysis, and estimates new travel that may be induced by highway expansion over and above that which is simply diverted from other regional highways or travel modes.

For policy makers faced with the controversial issue of induced travel, the critical issue is not whether highway capacity additions result in induced travel, but whether net societal benefits, after accounting for the external costs of induced travel, will exceed the public costs and social costs to be incurred. The application of SMITE in this paper shows how answers to this question can be obtained at the corridor level of analysis, and how the effects of induced travel can be incorporated into the evaluation process at a sketch planning level of analysis, especially in cases where four-step urban travel models are either unavailable or are unable to forecast the full induced demand effects.

The paper describes SMITE, the application, and the application results. The paper shows that SMITE can be used to provide useful information to assist policy makers in evaluating proposals for specific additions to highway capacity for corridor studies.

Major Corridor Investment-Benefit Analysis System

John G. Kaliski, *Cambridge Systematics, Inc*.; Stephen C. Smith, *Indiana Department of Transportation*; and Glen E. Weisbrod, *Economic Development Research Group*

Abstract

This paper discusses the Major Corridor Investment-Benefit Analysis System, which recently was developed for the Indiana Department of Transportation. The purpose of the system is to provide an analytical tool for use by INDOT in evaluating and comparing the impacts of major corridor highway investments in the state. The system combines a statewide travel demand model, a user benefit/cost analysis model, and a regional econometric model. The paper describes the conceptual approach behind the model. It also presents the results from an application of the model to analyze the transportation and economic impacts of the upgrade of U.S. 31 between Indianapolis and South Bend to Interstate level of service. Issues addressed by the model include the impact of travel time savings and other user benefits on business users of the highway; and the potential for the study corridor to attract new businesses or tourists as a result of improved access to markets.

This paper describes the Indiana Department of Transportation's Major Corridor Investment-Benefit Analysis System. It illustrates the use of the system to estimate the transportation and economic impacts of proposed major corridor improvements to U.S. 31 between Indianapolis and South Bend, Indiana.

The study estimates the transportation and economic impacts of major improvements to the entire 122-mile corridor between I-465 in Indianapolis and the U.S. 20 bypass in South Bend. The study area is defined as Hamilton, Tipton, Howard, Miami, Cass, Fulton, Marshall, St. Joseph, and Elkhart counties. The objectives of the study are to: evaluate the regional economic impacts of transportation improvements to the U.S. 31 corridor; ensure cost-effective public sector investment by comparing economic benefits to implementation costs; and enhance previous and ongoing U.S. 31 studies with information on a broader range of potential impacts.

Conceptual Approach

The traditional approach to highway benefit/cost analysis focuses on the benefits of the highway to its users, in terms of changes in travel time, safety, or operating costs. These changes can be quantified in monetary terms, and compared to the project's implementation costs to evaluate the cost-effectiveness of the project as a public sector investment. A broader approach, enabled by recent advances in economic forecasting and modeling techniques, considers not only the direct benefits of the highway on its users, but also the broader impacts on the regional economy. Economic benefits are defined as benefit to the economy such as the generation of additional jobs, business sales, or disposable income. The most common measure of economic benefit is change in disposable income, which reflects the change in wage income earned in the region. These benefits can be compared to economic costs, which represent the outflow of disposable income.

INDOT's Major Corridor Investment-Benefit Analysis System conducts such an economic impact analysis in five steps:

1. Conduct transportation network analysis. The Indiana Statewide Travel Model is used to generate projections of traffic volumes and travel times on the highway network in the corridor, as well as in the state as whole. Two forecasts are developed and compared – one assuming the improvements are implemented, and one assuming they do not occur.
2. Estimate user benefits. NET_BC, a user benefit-cost analysis model developed by Bernardin, Lochmueller & Associates, Inc., is applied to these estimates of traffic volumes and travel times to calculate the costs associated with travel time, safety, and vehicle operation in the corridor. The "no build" and "build" costs are compared to estimate the user benefits associated with the improvement.
3. Calculate direct economic benefits. A system of linked economic models is applied to calculate the money value of direct economic benefits for businesses. The portion of user benefits that accrue to businesses is estimated in terms of its impact on business costs and productivity. The changes in customer and labor market size are estimated based on the travel time changes, and applied in a business location model to identify the types of industries that may be attracted to the study area as a result of the highway improvements, and a projected number of additional jobs in each industry. Finally, direct tourist impacts are estimated based on changes in travel time from major tourist origin markets.
4. Project secondary economic benefits. A regional economic simulation model developed by Regional Economic Models, Inc. is applied to forecast the indirect and induced impacts of the direct economic benefits. This model generates estimates of changes in regional employment, income, and output.
5. Conduct benefit/cost analysis. These direct, indirect, and induced impacts are aggregated, discounted over time, and compared to the stream of capital and operating costs to determine an overall project benefit/cost ratio.

Study Area Economy and Transportation System

The study corridor runs from the northern suburbs of Indianapolis to the South Bend and Elkhart metropolitan areas on the Michigan border. Total population of the corridor was 791,000 in 1994. The corridor's population increased 1.4 percent annually between 1990 and 1995, and is projected to grow 0.9 percent annually between 1995 and 2020. Employment has been growing faster than population, with an annual increase of 2.4 percent between 1990 and 1995 and a projected annual increase of 1.5 percent through the year 2020. Forecast employment growth rates are about 50 percent higher than for the state of Indiana and for the United States.

U.S. 31 is the primary north/south route through north central Indiana. It is currently a four-lane divided highway, with varying levels of access control. In Hamilton County, access is primarily but not exclusively limited to the 12 signalized intersections along the highway. Howard County has 15 stoplights and numerous curb cuts and is fronted by significant amounts of retail and service development. Tipton, Miami, Fulton, and Marshall Counties are primarily rural and contain a total of only two stoplights. As U.S. 31 approaches U.S. 20 near South Bend, it is fronted by significant commercial activity and contains two stoplights, numerous curb cuts, and a center turn lane in some places. After intersecting U.S. 20, it becomes limited access and bypasses the city.

For the corridor as a whole, vehicle-miles of travel (VMT) are projected to increase by 59 percent and vehicle-hours of travel by 75 percent by the year 2020 (Table 1). Average travel speed is expected to drop somewhat from 39.7 to 36.1 miles per hour, under the baseline scenario in which U.S. 31 is not upgraded.

The largest increase in traffic is projected to occur in high-growth Hamilton County, where traffic will nearly double between I-465 and SR 431 (Table 2). Due to increased traffic volumes, total travel time between I-465 and SR 26 in Kokomo is expected to increase by roughly five minutes by the year 2020. Traffic volumes are also projected to increase in the northern part of the corridor, although travel times from Kokomo to South Bend will not be significantly affected.

Route Improvement Concept

The proposed major corridor improvement concept for U.S. 31 is for an upgrade of the corridor to Interstate design standards. The Interstate design standard is characterized by total access control; two (or more) travel lanes in each direction; and posted speeds of 55 miles per hour in urban areas and 65 miles per hour in rural areas. The proposed highway improvement includes construction of a new east-side bypass of Kokomo and a new freeway-to-freeway interchange with I-465 (Figure 1).

Transportation Impacts

The proposed improvement is projected to lead a seven percent increase in VMT throughout the study area, compared to the "no build" forecast that assumes no changes to existing U.S. 31.[1] The average free-flow speed along U.S. 31 from I-465 to the U.S. 20 bypass would increase to 60.3 miles per hour, compared with 50.3 miles per hour in the no-build forecast.[2] For all segments of the statewide highway network in the study area, average free-flow speed would increase from 36.0 to 40.1 miles per hour. With this improvement in average speeds, vehicle-hours of traffic (VHT) would decrease despite the increase in overall VMT. VHT is projected to decrease 4.3 percent in the study area and 1.3 percent for the state as a whole.

Average daily traffic (ADT) would be expected to increase significantly along most segments of U.S. 31, with an average increase of approximately 45 percent for the corridor as a whole (Table 3). In absolute numbers of trips, the increase would be largest at the southern end of the corridor. Average daily trips would decrease on many of the parallel north-south routes, which would be characterized by slower speeds and longer driving times than U.S. 31.

Due to the increase in average free-flow speeds along U.S. 31, the total travel time along the corridor between I-465 and the U.S. 20 bypass would decrease more than 21 minutes. Adjusting for the elimination of signalization, the total decrease in travel time would be closer to 35 minutes along the entire corridor.

[1] This forecast excludes potential diversion of trips among origin/destination pairs, so that total VMT statewide does not change significantly.

[2] Actual speeds in the no-build forecast are lower than 50.3 miles per hour due to signalization.

User Benefits

The user benefits attributable to the U.S. 31 corridor improvement fall into three categories:

1. Travel time savings reflect the dollar value of the reduction in VHT that is associated with the project. Over the 30-year analysis period, the cumulative value of these travel time savings for trips originating in Indiana is $5.3 billion in 1997 dollars.
2. Safety cost savings reflect the projected reduction in the number of accidents that would occur as a result of the improvement in the functional class of the facility, as seen in the reduction in congestion and the level of entering and exiting traffic. By the year 2020 the annual number of accidents in the state is expected to decrease by approximately 2,600, or about two percent. Using standard dollar values for accident costs by type, the cumulative savings over the 30-year analysis period for trips originating in Indiana is $2.6 billion in 1997 dollars.
3. Vehicle operating cost changes reflect changes in average operating speed. With the decrease in congestion and signalization associated with the highway improvement, autos and trucks will be operating at speeds higher than their optimal speed for maximizing efficiency and fuel economy. Consequently, cumulative operating costs for the period 2005 to 2034 are expected to increase $537 million for automobiles and $34 million for trucks, measured in 1997 dollars.

The cumulative total of all user benefits for trips originating in Indiana over the 30-year analysis period is $7.3 billion in 1997 dollars (Table 4). The majority (72 percent) of these benefits are the result of the travel time savings.

Personal auto trips account for 66 percent of the user benefits, or $4.8 billion in 1997 dollars over the 30-year period. The portion of auto user benefits associated with commuting to and from work does not affect business costs, except for those cases where it affects employee work hours (applicable to relatively few jobs) or prevailing wage rates (applicable mostly in competitive urban labor markets). The portion of auto user benefits associated with recreational and social trips is a quality of life benefit, but does not affect regional income flows. Because these benefits have no multiplier effects, they are not considered further in the economic analysis.

Economic Impacts

The highway improvement project would produce three types of direct economic impacts:

1. Expansion of existing businesses associated with the direct business cost impact of the user benefits. These impacts are measured in terms of changes in cost and productivity measures for specific industries.
2. Attraction of new businesses to the study area associated with the market access effects of the highway improvement. These impacts are measured in terms of direct new jobs by industry.
3. Changes in tourist activity in the corridor associated with the market access affects of the highway improvement. These impacts are measured in terms of changes in visitor-days by type of visitor.

These direct economic impacts produce secondary impacts in the form of increased sales for businesses producing intermediate products and services (indirect impacts), and increased sales for businesses benefiting from consumer spending from workers in the direct and indirect jobs (induced impacts). The indirect and induced impacts are measured in terms of changes in regional employment, output, or income.

Business Cost Savings

Travel time savings and safety cost savings for trucks represent a real reduction in business operating costs, which are only partially offset by increased vehicle operating costs. These benefits accrue to the for-hire trucking industry, as well as to industries that own and operate private fleets. Although concentrated in the study area, these benefits also would be experienced by trucking companies and other businesses based elsewhere in Indiana who ship to the study area. The cumulative value of these benefits statewide is $549 million in 1997 dollars.

The portion of auto travel time savings and safety cost savings that is associated with "on-the-clock" work trips represents a change in the productivity of labor (for workers' time) and capital (for business-owned automobiles). These are partially offset by the increase in business auto operating costs. The cumulative value of the direct business auto user benefits over the 30-year analysis period is $0.9 billion statewide in 1997 dollars. Industries with significant amounts of business auto travel primarily include: transportation service industries, such as taxi and limousine services; businesses that deliver products, such as certain types of restaurants and retail businesses; and businesses with professional or sales staff who travel for client meetings, including real estate, finance, business service, home health care, and other personal service industries.

Business Attraction Impacts

The highway project would enhance the attractiveness of business locations in the study area in several ways:

- Connections to outside areas. The highway project would improve connections from points throughout the study area to Indianapolis and the rest of central and southern Indiana, as well as further south to Kentucky and Tennessee. It also would improve connections from the entire study area to western Michigan, where urban areas such as Grand Rapids, Benton Harbor, and Muskegon support a large number of businesses producing motor vehicle parts, appliances, office furniture, and other durable goods. In addition, the central and southern portions of the corridor would improve connections with important origin and destination markets in Detroit and northern Ohio, as well as Chicago and Milwaukee.
- Extension of labor market and shopping areas. The reduction in travel times expected as a result of the U.S. 31 improvement would extend the labor market (defined as 30 minutes travel time) of most cities located along the corridor more than 10 percent. The increase would be most significant for the smaller cities in the central portion of the corridor such as Peru, Rochester, and Plymouth, where labor markets would increase more than 20 percent. The expanded labor market would help attract labor-intensive businesses to these locations, overcoming some of the concerns about the tight labor market that many economic development agencies in the corridor see as a constraint on future growth.
- Extension of delivery service areas. The highway project would extend the one-day delivery service area for truck trips (generally defined as six hours or approximately 250 miles)

moving into or out of the study area. The expected 35 minute reduction in travel times along the corridor would enable businesses to more effectively serve customers in states such as Kentucky, Tennessee, or Michigan. With the travel time improvements, a one-day truck trip from Kokomo would be able to serve markets including Chicago, Milwaukee, St. Louis, Detroit, Cleveland, Columbus, Cincinnati, and Louisville.

The analysis identified industries that are dependent on highway access, and have the potential for attraction to the study area based on the highway benefits. In general, these businesses depend on high volumes of truck shipments and timely delivery of supplies. Approximately 200 direct new jobs are expected to be attracted in these industries as a result of the highway project. These direct jobs would be concentrated in five industries: 1) motor vehicles and parts; 2) fabricated metal products; 3) rubber and plastics; 4) electrical equipment; and 5) retail trade. The actual business attraction will depend on the extent to which the state and the region market the highway improvement and implement complementary economic development incentives.

Tourism Impacts

The U.S. 31 improvement would enhance the region's tourist activity in several ways:

- Improved access to the South Bend area from central and southern Indiana. The highway project would enhance connections and reduce travel time between the large base of tourism activity in South Bend and Elkhart and origin markets to the south. It also would enhance the competitiveness of these markets for conventions and business meetings.
- Improved access to Indianapolis from western Michigan and the South Bend area. Access to Indianapolis from the western Michigan market would improve due to the reduction in travel times along U.S. 31. In addition, Indianapolis could become more attractive as a day trip or weekend trip from the South Bend area, in part attracting side trips from visitors whose primary destination is South Bend.
- Increase in the frequency and size of motor coach tours. While most tourists are from within the state, a number of coach tours from the Midwest region and Kentucky currently visit the U.S. 31 corridor. Interstate access is important to motorcoach tours and improvement of U.S. 31 would help attract coach tours to the central corridor area where there is currently no Interstate access.

The total number of annual visitor-days to the study area is projected to increase by 90,000, approximately a two percent increase in the number of annual visitor-days in the region. This increase will be partially offset by a decrease in tourist activity in the rest of the state, as some trips shift from Indianapolis and other markets to South Bend and other parts of the corridor. Additional visitors will contribute to the regional economy by spending money in various sectors. The direct spending impact of the additional visitor-days in the study area is estimated at $8 million per year. The industries that will benefit from the direct spending include hotels and lodging ($3 million), restaurants ($2.4 million), personal services, and retail trade.

Cumulative Economic Impacts

The cumulative effect of these changes would be to create an additional 5,010 jobs by the year 2034, the end of the forecast period (Table 5). These would include 1,880 jobs in the study area and 3,130 jobs in the rest of the state. Although the rest of the state is projected to lose some jobs and tourist activity to the study area, it will experience an overall employment gain as a result of two factors: direct business cost savings experienced by manufacturers, distributors, and motor carriers based elsewhere in the state who ship goods to the study area; and increased demand for business and financial services, which are concentrated in Indianapolis, from industries in the study area.

These jobs would be distributed among several industries, concentrating in services and trade. The employment would be phased in over two decades. Business sales are projected to increase a cumulative total of $3.9 billion over the 30-year analysis period in the study area, with a $4.8 billion increase in the rest of the state. Real disposable income is projected to increase $1.8 billion in the study area and $3.0 billion in the rest of the state.

Benefit/Cost Analysis

A benefit/cost assessment of a proposed highway investment involves comparing the entire stream of benefits resulting from the construction of a project over a specific period of years with the entire stream of costs over the same period. For the U.S. 31 analysis, both the benefit and cost estimates are presented in 1997 dollars, and are discounted at a rate of seven percent per year to compute their present value. Discounting compensates for differences in the timing of benefits and costs over the analysis period. The analysis period is from 2005, the year construction begins, until 2034.

The benefit/cost framework requires analysis of the following costs (Table 6):

- Capital costs. The capital cost for the U.S. 31 improvement concept is $1.1 billion, including $798 million in construction costs and $288 million in right-of-way costs. The construction cost total includes roadway, bridge, interchange, grade separation, and traffic maintenance costs; a 20 percent contingency is excluded from these calculations. The right-of-way costs include land acquisition, land improvement, and relocation.
- Operations and maintenance costs. The annual operations and maintenance costs for the U.S. 31 improvement is assumed to be $370,000 per year, beginning in the year 2010.

The total present value of these costs is $894 million in 1997 dollars.

The benefit/cost framework requires analysis of the following benefits:

- User benefits for personal auto use. The travel time, safety, and operating cost benefits that accrue to personal auto travelers (e.g., for commuting, social, and recreational trips) can be valued in monetary terms. However, these are separated from the user benefits for business auto and truck use, which generate economic impacts because they create additional income.
- Direct, indirect, and induced economic impacts. Economic impacts are associated with the expansion of existing businesses, the attraction of new businesses, and changes in tourist activity. These impacts are reported together to eliminate possible double-counting. They are measured in terms of changes in real disposable income.
- Residual value. The residual value represents the estimated value of the highway structure and pavement at the completion of the 30-year analysis period, given standard assumptions about depreciation rates. It is estimated at $610 million in 1997 dollars.

The total present value of all benefits is $2.9 billion in 1997 dollars. The present value of the economic benefits is $1.3 billion, or slightly less than half of this total. The net benefit is nearly

$2.0 billion, which indicates that the project would create a net benefit for the regional economy. The benefit/cost ratio is 3.2 to 1.

The following types of benefits and costs are not included in the benefit/cost analysis: 1) disbenefits associated with the disruption and detouring of traffic during the construction period; 2) disbenefits associated with the project financing, such as the cost of debt servicing; 3) benefits of partial operation of the upgraded facility during the construction period; 4) benefits resulting from the expenditures for construction of the proposed project, which are temporary in nature; and 5) shifts in business sales associated with localized changes in pass-by traffic and access to businesses abutting U.S. 31.

Table 1: Current and Forecast U.S. 31 Corridor Population, Employment, and Traffic

	1995	2020	Percent Change
Population (thousands)	802	997	24
Employment (thousands)	498	645	30
Vehicle-miles of travel (thousands)	13,622	21,718	59
Vehicle-hours of travel (thousands)	343	601	75
Average speed (miles per hour)	39.7	36.1	-9

Source: Woods and Poole Economics, Inc.; Cambridge Systematics, Inc., Indiana Statewide Travel model.

Table 2: Current and Forecast U.S. 31 Travel Times and Traffic Volumes

	Free-Flow Travel Time (min.)[1]		Average Daily Traffic	
Highway Segment	**1995**	**2020 (No-Build)**	**1995**	**2020 (No-Build)**
I-465 to SR 431	6.7	8.2	39,200	78,800
SR 431 to SR 26	32.9	35.3	24,200	39,800
SR 26 to U.S. 35 (N)	12.1	12.5	28,200	36,400
U.S. 35 (N) to U.S. 24	14.3	14.4	18,400	23,800
U.S. 24 to U.S. 30	46.7	46.6	12,600	18,500
U.S. 30 to U.S. 20	22.7	22.8	20,300	35,200
Corridor Total	**138.5**	**143.2**	**22,000**	**36,100**

(1) Travel times assume free-flow speeds. Actual travel times in the no-build scenario are higher due to signalization.

Source: Cambridge Systematics, Inc., Indiana Statewide Travel Model.

Table 3: Projected Changes in Average Daily Traffic from U.S. 31 Corridor Improvements, 2020

	Number of Trips			Travel Time (minutes)(1)		
U.S. 31 Link	**No-Build**	**Build**	**Difference**	**No-Build**	**Build**	**Difference**
I-465 to SR 431	78,800	122,200	43,400	8.22	6.06	-2.16
SR 431 to SR 26	39,800	61,400	21,600	35.30	28.61	-6.69
SR 26 to U.S. 35 (north leg)(2)	36,400	41,900	5,500	12.53	14.09	1.56
U.S. 35 (north leg) to U.S. 24	23,800	37,000	13,200	14.43	12.03	-2.40
U.S. 24 to U.S. 30	18,500	30,700	12,200	46.64	39.43	-7.21
U.S. 30 to U.S. 20 bypass	35,200	42,900	7,700	22.79	18.97	-3.82
I-465 to U.S. 20 bypass	**36,100**	**52,600**	**16,500**	**143.17**	**121.91**	**-21.26**

(1) Travel times assume free-flow speeds. Actual travel times in the no-build scenario are higher due to signalization.

(2) Data shown are for the existing U.S. 31 alignment, which will continue to represent the shortest path through the metropolitan area. The projected number of average daily trips on the eastside bypass is 9,900.

Source: Cambridge Systematics, Inc., Indiana Statewide Travel Model.

Table 4: Summary of User Benefits from U.S. 31 Corridor Improvements

Millions of $1997, Cumulative 30-Year Change, Trips Originating in Indiana Only

	Non-work Auto	**Work Auto**	**Truck**	**Total**	**Percent**
Travel Time Savings	$3,451	$1,389	$430	**$5,270**	72
Safety Cost Savings	1,785	667	153	**2,604**	36
Vehicle Operating Cost Changes	(408)	(129)	(34)	**(571)**	-8
Total	**$4,827**	**$1,926**	**$549**	**$7,303**	
Percent	66	26	8		

Source: Bernardin, Lochmueller, and Associates, Inc.

Table 5: Projected Long-Term Economic Impact of U.S. 31 Corridor Improvements

Difference from Control Forecast

	2010	**2015**	**2020**	**2025**	**2030**
Study Area					
Total Employment (Thousands)	0.61	1.03	1.36	1.66	1.87
Population (Thousands)	0.19	1.24	2.09	2.80	3.31
Business Sales (Millions of $1997)	$ 40	$ 86	$136	$191	$232
Disposable Income (Millions of $1997)	$ 29	$ 47	$ 64	$ 81	$ 95
Total State					
Total Employment (Thousands)	1.35	2.48	3.30	4.04	4.66
Population (Thousands)	0.52	3.31	5.56	7.43	8.84
Business Sales (Millions of $1997)	$100	$208	$305	$410	$503
Disposable Income (Millions of $1997)	$ 80	$130	$173	$216	$255

Source: Cambridge Systematics, Inc., Major Corridor Investment-Benefit Analysis System.

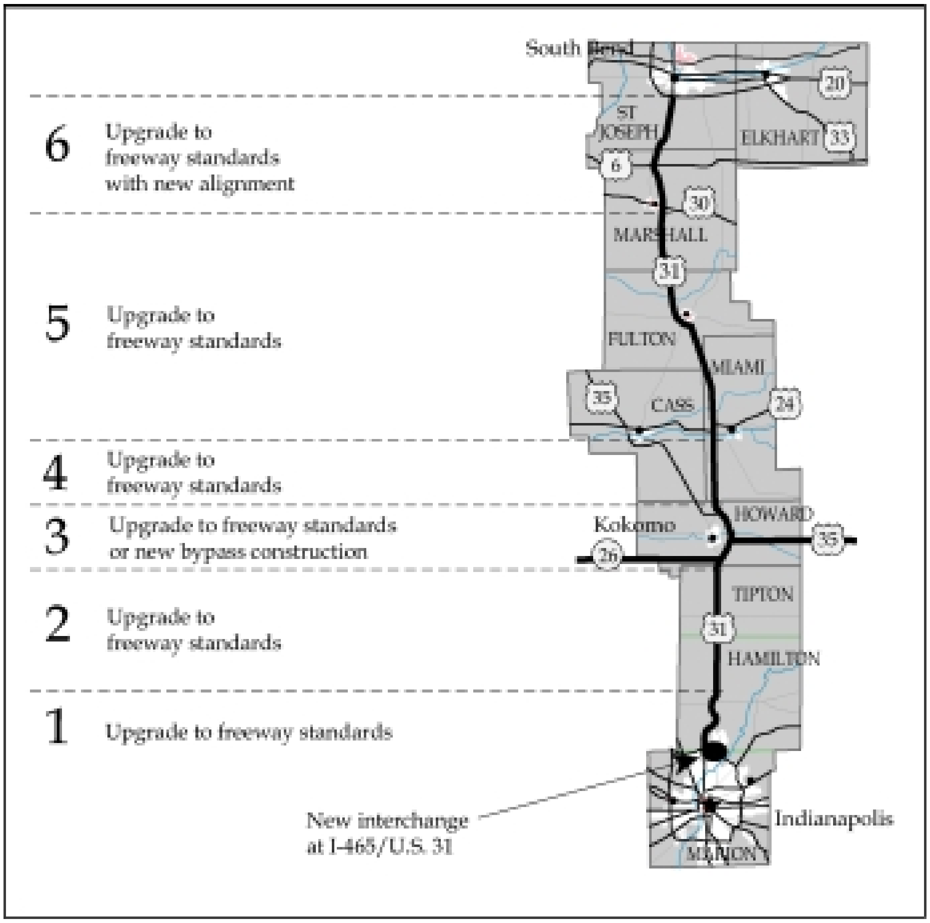
Table 6: Economic Benefit/Cost Analysis of U.S. 31 Corridor Improvements

Millions of $1997, Net Present Value, Seven Percent Discount Rate, Cumulative Change, 2005-2034

Benefits	
Personal Auto User Benefits	$1,468
Economic Benefits	1,326
Residual Value	75
Total Benefits	**$2,869**
Costs	
Construction	$ 891
Operations and Maintenance	3
Total Costs	**$ 894**
Net Benefit	**$1,974**
Benefit/Cost Ratio	**3.2**

Source: Cambridge Systematics, Inc., Major Corridor Investment-Benefit Analysis System.

Figure 1: U.S. 31 Route Improvement Concept



Lee County Variable Pricing – Early Findings

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Abstract

In an effort to manage traffic congestion, variable pricing began August 3, 1998, on two heavily traveled toll bridges in Lee County, Florida. Bridge travelers can now receive a 50 percent discount on their toll by traveling during specific discount periods - 6:30 am to 7:00 am, 9:00 am to 11:00 am, 2:00 pm to 4:00 pm, and 6:30 pm to 7:00 pm. This project is one of the few variable tolling projects in the United States and is part of the Federal Highways Value Pricing Pilot Program. As such, user response to variable pricing, and the resulting impacts on traffic, are being carefully monitored.

This paper presents some early findings in the Lee County Variable Pricing Project, including traffic data analysis and user surveys. Traffic before variable pricing began was compared to traffic patterns with variable pricing under way. Data includes detailed transaction records of each vehicle using either of the two bridges, toll plaza queues, average vehicle occupancies, and transit usage. Additionally, detailed speed studies were performed to determine if drivers are significantly altering their speed in order to obtain the toll discount.

One user survey, a roadside survey taken prior to variable pricing, was analyzed using linear regression and multinomial logit modeling. This survey provides insight into the characteristics of variable pricing users and their primary reasons for participating – or choosing not to participate.

The paper then summarizes what has been found during this early phase of the Lee County variable pricing project and details the data collection efforts that are still to be performed.

Introduction

Lee County

As part of the Federal Highway Administration's (FHWA) Value Pricing Pilot Program, Lee County, Florida, began a variable pricing project on two local toll bridges. As part of the FHWA program, research into the impact of variable tolls on transportation in the county is particularly important. This paper examines some of the early results obtained through intensive research of this project.

Lee County is located along Florida's southwest coast. It has a population of 400,000 citizens, the majority of whom reside in the cities of Cape Coral and Fort Myers. These two cities are separated by the Caloosahatchee River (see Figure 1). The majority of employment is in Fort Myers and, therefore, the four bridges connecting Cape Coral to Fort Myers accommodate a

great deal of the commuter traffic in the County. Two of these bridges, the Cape Coral and Midpoint are tolled, and variable pricing was implemented on these two bridges only.
This geography is beneficial to the study of variable pricing since applying variable tolls on these two toll bridges will impact traffic throughout the county. Additionally, Lee County does not suffer from severe congestion. Therefore, any changes resulting from variable pricing will likely be due to economic factors and not congestion related. Also, latent demand will not distort the changes in traffic flows. These three factors contribute to the cleanliness of the data that is collected. However, Lee County is one of the fastest growing counties in the country and congestion will likely occur in the future. With variable pricing in place now, citizens may have the mindset to avoid peak period travel – potentially extending the useful life of many of Lee County's roadways.

The Variable Pricing Program

The Midpoint Bridge opened in October 1997. Prior to its opening, tolls were raised from $0.75 to $1.00 on the Cape Coral Bridge to help finance the construction of the Midpoint Bridge. At that time, the County Commission promised citizens they would not raise bridge tolls for the foreseeable future. This led to the current variable pricing toll discount scheme where tolls are discounted by 50 percent in the periods just before and just after the morning and evening peak periods (6:30 am – 7:00 am, 9:00 am -- 11:00 am, 2:00 – 4:00 pm, and 6:30 – 7:00 pm) for those patrons paying the toll electronically.

Data Collection & Analysis

Overview

The FHWA has sponsored a select few variable (value) pricing projects across the U.S. in an effort to better understand travelers' behavioral changes caused by variable tolls. Extensive research efforts are an important part of each of these projects. Lee County data collection efforts include:

- roadside interview and mail back travel surveys
- telephone interview surveys
- nominal grouping sessions and focus groups
- travel time surveys
- average vehicle occupancy studies
- toll plaza queueing studies
- traffic data at the toll plazas and from around the county
- transit ridership
- spot speed studies

This paper examines some early findings from the study related to toll bridge traffic data, electronic toll collection tags sales, transit ridership, spot speeds, and a travel survey.

The majority of the data comparisons presented in this paper compare data collected from January to July 1998 (pre-variable pricing) to data collected from August to December 1998 (during variable pricing, variable tolls began August 3, 1998). As with many cities in the U.S., and around the world, traffic fluctuates by time of year in Lee County. Generally, there is more traffic during January to April than any other part of the year due to tourists in the county. Fortunately, the Midpoint and Cape Coral bridges are not significantly impacted by tourist traffic. As this project continues, and additional data are available, data comparisons between similar months in 1998 versus 1999 will be used. Data from 1997 is not used since the Midpoint Bridge opened in October 1997, significantly altering travel patterns in the county.

Electronic Toll Collection (ETC) Tags

One of the more complex features of the variable pricing program in Lee County is the many options available with which to pay tolls. Users always have the option to pay their entire toll, $1.00, by cash. Users can also purchase electronic toll collection (ETC) tags, termed "LeeWay" tags. There are a number of different LeeWay programs available. The most popular includes an annual program that cuts the $1.00 toll to $.50 for each bridge crossing and, for additional money, users can purchase a LeeWay tag program that allows them unlimited free passage on the toll bridges. Users with these programs are identified at the toll plaza through the information embedded on their ETC tag and can pay their reduced fare either electronically or by cash. In addition, some users purchase an ETC tag without any special program, allowing them the convenience of paying electronically and making them eligible for variable pricing discounts.

Variable pricing (discount tolls) are available only to those people who pay electronically. Therefore, it is hypothesized that, over the life of the project, the percentage of tags that are eligible for variable pricing will increase as more people (a) learn about variable pricing and (b) learn how easy and reliable it is to pay tolls electronically. As shown in Figure 2, the percentage of all ETC tags issued (60,000 total tags issued as of February 1999) that are eligible for variable pricing has been increasing over the life of the project to approximately 37 percent in November 1998. One of the county's goals is to encourage more electronic toll payments and, therefore, more users in the variable pricing program and increased toll payment efficiency.

Bridge Traffic Data

At each toll plaza, data such as number of axles, time, and payment method are recorded on each vehicle that crosses the bridge. The research performed for this project focuses on three important variables: the time of each crossing, the number of vehicles, and payment methods. Analysis of this data will indicate what impact variable tolls have had on bridge traffic.

First, total traffic at the Midpoint Bridge is examined. Results from Midpoint Bridge are examined in this paper both for simplicity and because, of the two toll bridges, it is the least impacted by tourist traffic (although neither Cape Coral nor Midpoint Bridges are significantly impacted by tourist traffic). Figure 3 indicates the percentage change in the average half-hourly traffic from prior to variable pricing to during variable pricing. The half-hourly traffic volumes from the pre-variable pricing period were increased by 9 percent across the day to account for the lower average daily traffic (ADT) during that timeframe. By altering the data in this way, the total changes in traffic throughout the day total 0 percent, making the change in traffic due to variable pricing easier to see graphically.

Results indicate a 7 percent increase in traffic during the early morning discount period (6:30 – 7:00 am). Traffic showed no significant change (changes less than 2.5 percent were not statistically significant at the 95 percent level of confidence) in the remainder of the half-hour periods throughout the day. As expected, almost all peak period traffic experienced a relative decrease after the start of variable pricing. However, these changes were too small to be statistically significant at the 95 percent level of confidence. The number of additional vehicles per day from 6:30 am to 7:00 am was 61, while there were 126 fewer vehicles per day during the morning peak period from 7:00 am to 9:00 am.

As discussed in the previous section of this paper not all traffic that crosses the toll bridges is eligible for variable pricing discount. Only those patrons using LeeWay PrePay (paying the toll electronically) are eligible for variable pricing discounts. In fact, only 23 percent of all Midpoint daily traffic is eligible for discounts. Similar results were obtained at the Cape Coral Bridge, where again, 23 percent of bridge traffic is eligible for variable pricing toll discounts.

Mode Changes

Variable pricing reduces the cost of automobile travel across the toll bridges during specific periods of the day. This could potentially increase the percentage of single occupant vehicles (SOV) traveling across the toll bridges, while decreasing the percentage of transit riders, carpools, and vanpools.

To determine if transit ridership has been significantly impacted by variable pricing, ridership records from LeeTran were carefully examined. Three transit routes were investigated:

- Route 30 – the only route that cross the Cape Coral Bridge
- Route 120 – the only route that crosses the Midpoint Bridge
- Route 70 – crosses the Caloosahatchee Bridge

All three routes connect residents in Cape Coral to employment and shopping in Fort Myers. Routes 30 and 120 cross the toll bridges, and their ridership would be most impacted by variable pricing discounts. Route 70 crosses one of the free bridges and will be used as a control data point for transit ridership across the Caloosahatchee River. It was hypothesized that variable pricing would not impact transit in this area since transit's mode share is less than one percent and the vast majority of the people taking transit are "captive" users.

LeeTran records the number of passengers that board each bus run and the start time for that run. One-week (Monday to Friday) periods of data were analyzed for each month from April 1998 to December 1998. Using this data, the average daily ridership on each route for specific periods of the day (peak periods: 7am to 9am and 4pm to 6:30pm; variable pricing discount periods: 6:30am to 7am, 9am to11am, 2pm to 4pm, and 6:30pm to 7pm; other periods: all other times from the first bus run to the last run) was calculated for pre-variable pricing (April to July 1998) and during variable pricing (August to December 1998).

Results from the control route, Route 70, were analyzed first to examine if there were any changes in transit ridership on this corridor. These changes would not be attributable to variable pricing. During discount times, it was found that transit ridership increased by 10 percent (see Figure 4), and there were no significant changes during other periods of the day. Next, results from Routes 30 and 120 were examined. It was hypothesized that there would be no significant change in ridership on these routes when compared to changes on our control route, #70. Results validated this hypothesis (see Figure 5), as the two routes over the toll bridges experienced a 6 percent increase in ridership. It can be concluded that variable pricing has not negatively impacted transit ridership.

In addition to LeeTran data, results of a recent telephone survey of 400 Lee County residents who frequently cross the bridges were examined. Respondents were asked if they had altered their mode of travel since August 1998. Only 8 indicated that they had changed their mode, and of those, no one responded that they changed modes from transit. Therefore, it was concluded that variable pricing has not significantly impacted transit ridership.

Variable pricing discounted tolls also have the potential to negatively impact the number of carpools and vanpools on the toll bridges. To determine if variable pricing toll discounts were causing people to abandon their carpools and vanpools in favor of SOV, average vehicle occupancy (AVO) studies were conducted. These studies attempt to record the number of people traveling in each vehicle on the Cape Coral, Midpoint, and Sanibel bridges. Due to the volume of traffic it was impractical to record occupants in every vehicle, but the majority of vehicles were observed. These studies were conducted in March, May, and October 1998 and the results can be seen in Figure 6 and Table 1.

As can be seen in Table 1, there has been a significant change in AVO during several of the study time periods. However, these changes are most prevalent on both the Cape Coral and Sanibel bridges. There is also a uniform decrease in AVO at both Cape Coral and Sanibel bridges. This is likely due to tourist traffic in the early months of the year and the fact that tourists generally have more people in their vehicles than regular commuters.

Results from the telephone survey indicate none of the 400 respondents switched modes from carpool or vanpools to SOVs after the start of variable pricing. These data leads us to conclude there has been a change in AVO, but it is not due to variable pricing. This aspect of the project will be further researched in upcoming surveys and AVO counts.

Spot Speed Studies

The premise for variable tolls is that some drivers will alter their travel behavior in order to obtain a lower toll. This is happening in Lee County, as the traffic data collected at the toll plazas indicates. The assumption is that people will either travel earlier or later to avoid the peak period (and peak toll). However, there is the possibility that drivers will drastically alter their speed on the road in order to obtain the variable pricing discount. Drivers might drive extremely slowly just before discount periods were to begin (potential “Slow Periods”) or very quickly just before discount periods ended (potential “Speeding Periods”). This could lead to a dangerous driving environment and possibly accidents.

To determine if this was happening, two methods of speed measurement were employed. This paper presents the results obtained when a radar gun was used to manually record the speeds of vehicles approaching both the Cape Coral and Midpoint toll plazas. Special traffic counters were also placed on the approaches to these toll plazas and they automatically recorded speeds of approaching vehicles. Thousands of data points were collected at the toll plazas during both potential slow and speeding periods both before and after August 1998.

Tables 2 and 3 graphically depict the spot speed study results. Variable pricing had no impact on the overall speed of vehicles at the toll plazas. Although speeds did change at both the Midpoint and Cape Coral toll plazas, the changes appear to have little to do with variable pricing. For example, at the Midpoint Plaza, average speeds increased in August 1998 and decreased in December 1998 relative to July 1998 speeds, for *both* potential slow and speeding periods. However, during the recording of more than 10,000 speeds (and thousands of additional vehicles that passed by during these times but whose speeds were not recorded), three vehicles did enormously alter their travel speeds. Two of the vehicles pulled over and waited for the discount times to begin and one vehicle approached the toll plaza at greater than 80 mph.

Origin-Destination Survey

In May 1998 a roadside origin-destination survey, combined with a mailback survey, were conducted at all five bridges in Lee County. Over 2500 roadside interviews were successfully conducted along with 667 mailback surveys were completed and returned. Since this survey was conducted prior to the introduction of variable pricing, the concept of variable pricing had to be explained in the survey. Questions then focused on whether respondents planned to change their travel behavior, how it would change once variable pricing began, and socio-economic characteristics of the respondents.

Twenty-one percent of survey respondents stated that they would switch their travel times an average of four times per week due to variable pricing. This exceptionally high level of participation has not occurred. Investigation into exactly how incorrect this stated use of variable pricing was not undertaken. This may prove useful to determine since many stated preference surveys are used to gauge the potential impact of variable pricing in a community.

Despite the overly high estimate of variable pricing usage, multinomial logit models were created in order to build a model that would estimate variable pricing use based on numerous socio-economic characteristics. However, none of these models provided an accurate estimate on who would alter their travel times to obtain variable pricing toll discounts.
This finding is consistent with other literature on the users of SR-91, a variable pricing project in California. Although there are some similar characteristics in frequent users, the link between these characteristics and frequent use is weak. Many users of the system have an event (i.e., a meeting, doctor’s appointment, child’s birthday party) that cause them to use the toll road for that specific trip. This may be the case in Lee County as well, where people who change travel times to receive the variable pricing toll discount have widely varied demographic characteristics and reasons for changing travel times. The mailback survey scheduled for May 1999 will likely provide additional insight into this issue, where the survey in 1998 had far too many respondents stating they would use variable pricing that did not.

Despite the fact many respondents stated they would change their travel times to receive discounted tolls, the socio-demographic characteristics of those people were compared to the characteristics of those who stated they would not alter their travel times. This may be best described as a comparison of those people who would like to use variable pricing compared to those that would not. As can be seen in Table 4, 118 respondents stated they would change their travel time to receive the toll discount, while 438 stated they would not. Not all of these respondents completed all of the socio-demographic questions, causing smaller sample sizes for some of the characteristics.

It was found that only two characteristics, household income and level of education, had a significant impact on the respondents stated use of variable pricing. Upon further investigation it was found that these two variables were strongly correlated and can therefore be considered almost as a single variable. It was found that the greater the education level (and income level), the less likely the respondent would be to change travel times to obtain the variable pricing discount. It is hypothesized that these individuals place a higher value on their time and therefore are less willing to alter their travel times.

Conclusions

To date, the traffic impacts of the Lee County variable pricing project have been basically as expected. During the first few months of the project there has been a steady increase in the number of patrons eligible for variable pricing discounts. There has also been a significant shift in traffic during the peak and discount periods. The largest shift in traffic is during the early morning discount period where there has been a 7 percent increase in traffic at the Midpoint Bridge. There has been a corresponding decrease in traffic during the morning rush hour.

The reduction in tolls during the discount periods has had no significant impact on transit ridership. Transit ridership will continue to be monitored, but it is unlikely that the toll discount will be enough to encourage many people off LeeTran (most of whom are transit dependent) and into their own automobile. Average vehicle occupancies have decreased on the Cape Coral Bridge since the introduction of variable pricing. It is hypothesized that this decrease is due to tourists using the bridge during the early months of 1998. This issue will be revisited during AVO studies in 1999.

The fear that many people would significantly alter their travel speed to obtain the variable pricing discount were unfounded. There is no significant difference between speed recordings taken before variable pricing and after variable pricing had begun. However, there are occasional vehicles that do alter their speed in a hazardous manner to obtain the discount. Lee County officials are addressing this problem.

Finally, the results from the mailback survey were inconclusive. Since this survey occurred before variable pricing began, people were asked if they intended to alter their travel behavior due to variable pricing. An overly large number stated they would. Nonetheless, the socio-economic characteristics of those people that stated they would alter their travel times were compared to those who stated they would not. The only characteristic that made a significant difference in people's use of variable pricing was the income/education level characteristic. The higher the income/education level of the respondent, the less likely they were to use variable pricing. Likely indicating they place a higher value on their time.

This paper presents findings from data obtained through December 1998. To date, the Lee County Variable Pricing Project has been a success, and these early study results were mainly as predicted. However, a great deal more data will be collected to better understand the motivations and socio-economic characteristics of users of the program and explain the few unexpected results found to date.

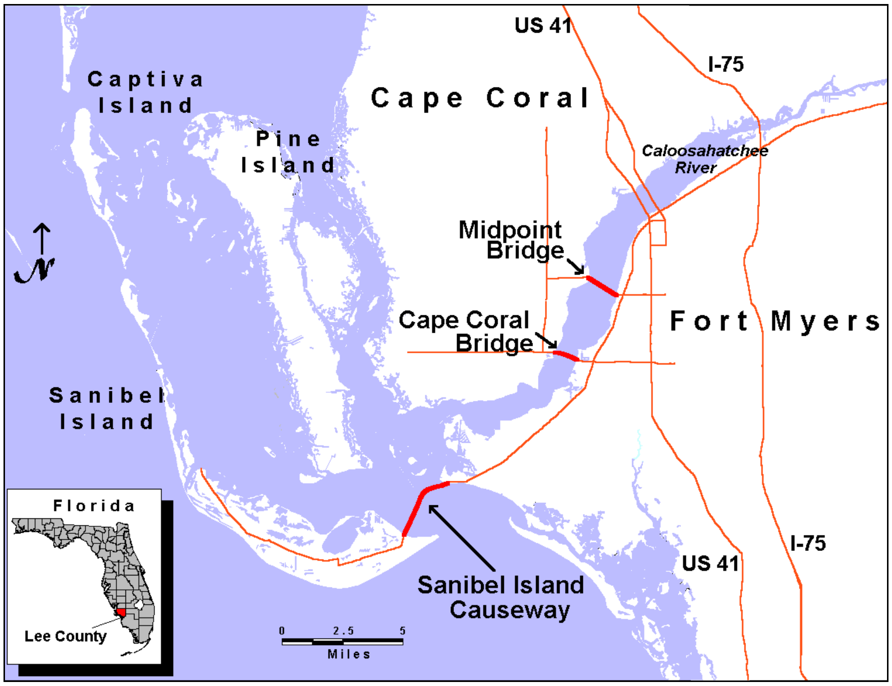

Figure 1: Lee County, Florida

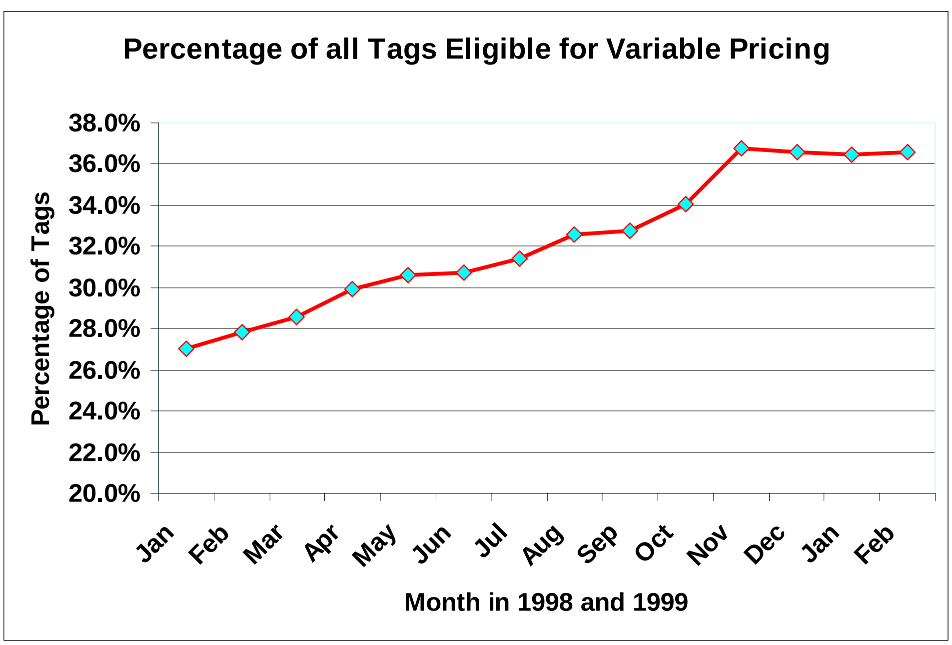

Figure 2: Percentage of LeeWay ETC Tags Eligible for Variable Pricing

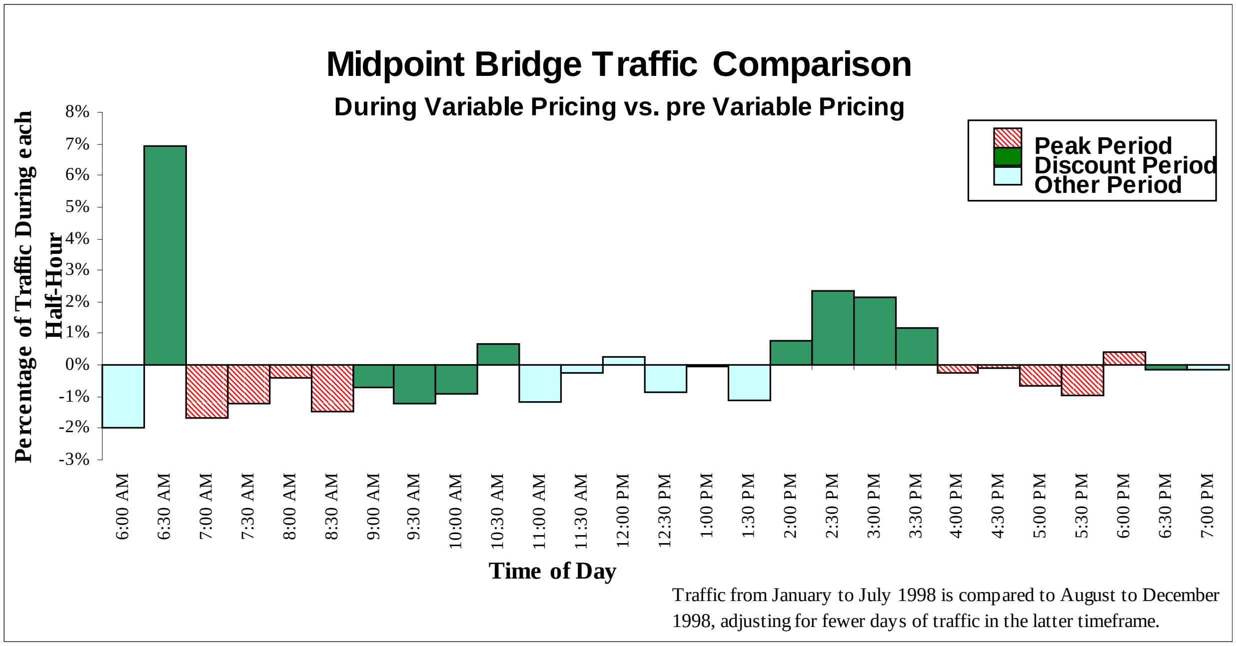

Figure 3: Change in Half-Hourly Traffic at Midpoint Toll Plaza

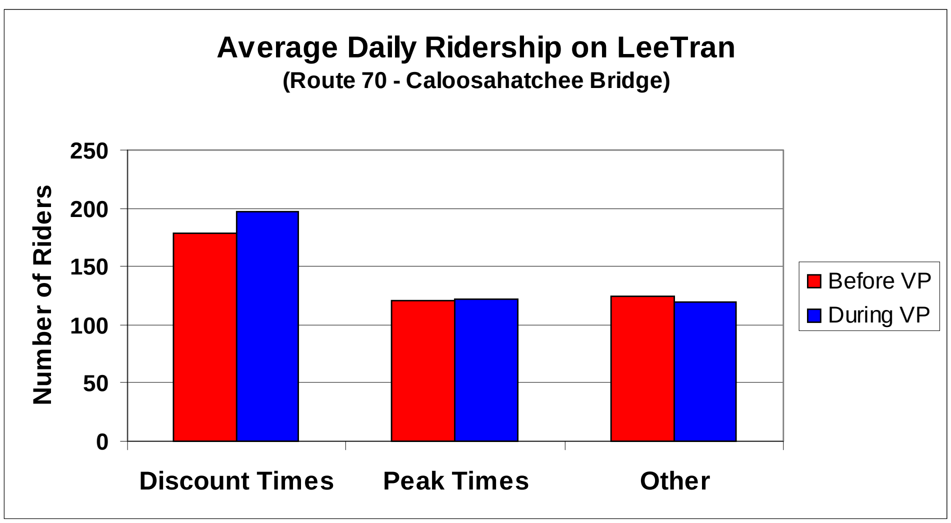

Figure 4: Ridership on Transit Route 120

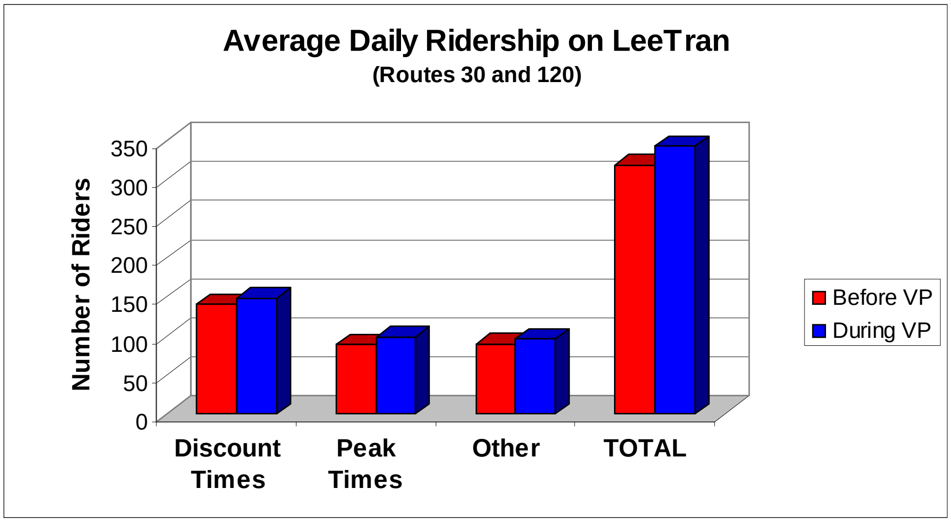

Figure 5: Ridership on Transit Routes 70 and 120

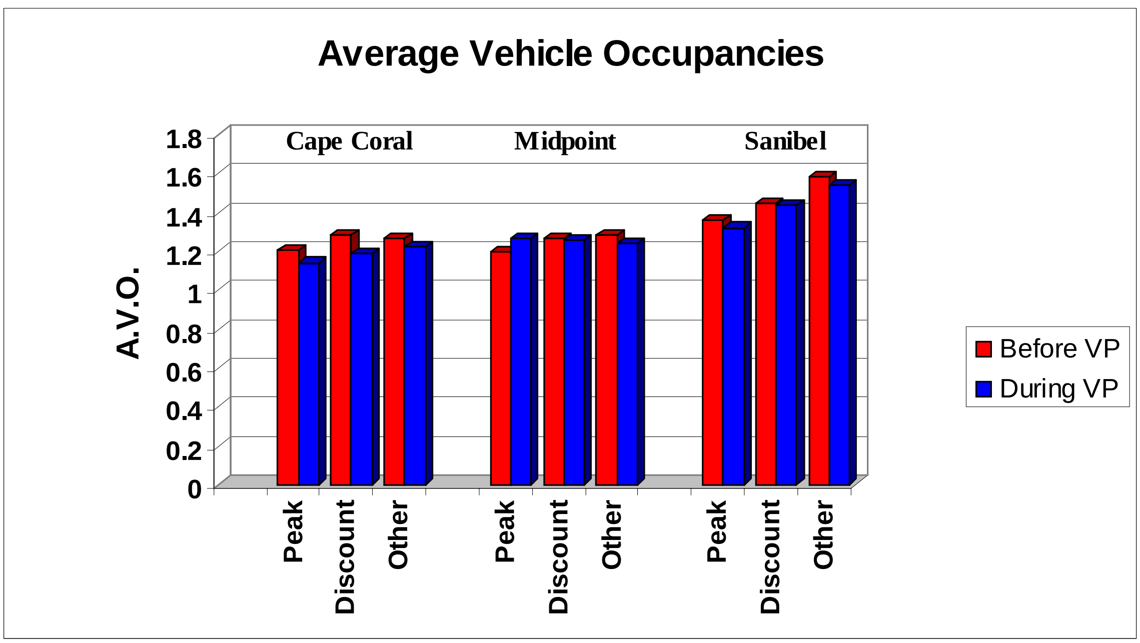

Figure 6: Average Vehicle Occupancy Study Results

Table 1: Average Vehicle Occupancy Analysis

Average Vehicle Occupancies					
Bridge	**Before VP**	**During VP**	**t-statistic**	**Statistically Different**	**Higher / Lower with VP**
Cape Coral					
Peak	1.206	1.140	11.536	YES	Lower
Discount	1.282	1.186	13.425	YES	Lower
Other	1.264	1.223	4.212	YES	Lower
Midpoint					
Peak	1.195	1.267	-10.678	YES	Higher
Discount	1.263	1.258	0.636	NO	Higher
Other	1.283	1.239	4.200	YES	Lower
Sanibel					
Peak	1.361	1.320	2.512	YES	Lower
Discount	1.446	1.437	0.456	NO	Lower
Other	1.581	1.538	1.703	NO	Lower

Minimum number of observations in any single field = 2400
t-tests conducted at 95% level of significance with t-Critical =1.96
Data for pre VP period taken from March & May 1998 observations
Data for VP period taken from October 1998 observations

Table 2: Spot Speeds at Midpoint Toll Plaza

Date	Average Speeds (MPH)	
	Potential Slow Period	Potential Speeding Period
June 1998	47.9	48.7
August 1998	49.6	49.8
December 1998	48.0	47.6

Table 3: Spot Speeds at Cape Coral Toll Plaza

Date	Average Speeds (MPH)	
	Potential Slow Period	Potential Speeding Period
June 1998	42.7	43.5
August 1998	42.2	42.3
December 1998	43.6	43.5

Table 4: Stated Use of Variable Pricing

Characteristic	Sample Size		Mean	
	YES	NO	YES	NO
Income Level*	105	386	2.82	3.43
Sex	115	433	1.50	1.48
Education Level*	115	424	3.05	3.41
# People in House	114	418	2.28	2.39
Age	116	432	4.44	4.43
# Vehicles in Household	114	424	1.94	2.01
Vehicle Class	118	438	1.97	1.93
# Months in Lee County	118	438	10.98	11.17
# People in Vehicle	118	437	1.37	1.32
Household Type	114	431	3.17	3.52

Note: t-statistics have been computed at 95% confidence interval. YES = would alter travel times To take advantage of variable pricing discounts. NO = would not alter travel time.
*= Variable is significant at the 95% confidence level

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