

# Destination and Mode Choice Models for Nonmotorized Travel

RONALD EASH

Until recently, few work programs of metropolitan planning organizations (MPOs) included planning for pedestrians and bicycles. This situation is changing as MPOs respond to the availability of federal funding for pedestrian and bicycle facilities, the efforts of bicycle and quality-of-life advocacy groups, and air quality conformity requirements that limit growth in vehicle trips. Walking and cycling cannot be introduced easily into MPO travel forecasting models due to the different scales of nonmotorized and vehicle trips. Analysis zones and coded networks for forecasting vehicle travel are typically too coarse for the trips of pedestrians and cyclists. Vehicle models also are based on certain theories of travel behavior that seem inappropriate for nonmotorized travel. Models for nonmotorized destination choice and vehicle versus nonmotorized mode choice have been calibrated and applied at the Chicago Area Transportation Study as part of a regional model. The two nonmotorized models feature a different zone system than the vehicle models and measure the difficulty of nonmotorized travel without a coded network. How these nonmotorized models were calibrated and implemented in the regional model is shown. Model estimates of walking and cycling trips are presented and compared against census work-trip data and a recent household travel survey.

Work programs of metropolitan planning organizations (MPOs) increasingly include planning projects for bicycle and pedestrian modes. For example, there were no specific nonmotorized projects in the fiscal year 1988 northeastern Illinois transportation planning work program (1), but in the current 1998 work program, \$290,000 is budgeted for planning a regional bike network, promoting cycling to shopping spots, and evaluating of central-area pedestrian facilities (2). Although this amount is a small fraction of the region's annual transportation planning budget of nearly \$19.2 million, it does not include funds spent on evaluating and programming the nearly \$32 million of bike and pedestrian facilities in the current 5-year transportation improvement program (3).

Three reasons can be cited for the heightened interest in planning for nonmotorized modes by MPOs. First, advocacy groups for cycling and quality-of-life issues have organized to voice their views in the transportation planning processes in many urban areas. In northeastern Illinois, the cycling advocacy group is especially active in the region's transportation planning and programming. Second, regions unable to meet national standards for ozone air quality must demonstrate that their plans and programs conform to a state plan to attain these standards. Shifting travel from vehicle to nonmotorized modes helps reduce growth in vehicle-miles, and it is a positive conformity strategy. And third, arguably the most important reason to plan for nonmotorized travel is the federal funding for pedestrian and bicycle facilities available through FTA and FHWA funding programs. Pedestrian and cycling projects that help nonattainment regions reach air quality standards can receive federal funds through the Conges-

tion Mitigation and Air Quality Improvement Program (U.S. Code, Title 23, Section 149). The Surface Transportation Program also funds transportation enhancement projects, which include bicycle and pedestrian facilities [U.S. Code, Title 23, Section 101(a)].

## EXISTING TRAVEL DEMAND MODELS AND NONMOTORIZED TRAVEL

The network-based models used by MPOs forecast vehicle travel at an unsuitable scale for pedestrian and bicycle travel. Most walking and biking trips take place inside these models' large analysis zones, and intrazonal trips often are ignored or crudely estimated by vehicle models. Coded highway networks for traffic assignment are too coarse for walking and biking trips since they exclude many local streets favored by pedestrians and cyclists. Although links representing local streets, sidewalks, bike paths, and other pedestrian ways can be coded, adding all facilities that might be traveled reasonably by pedestrians and cyclists would greatly increase the number of links and nodes in the network.

The development of nonmotorized models has been hindered by the lack of walking or cycling travel data for model calibration. Although less often the case today, it was common for MPO-sponsored household travel surveys to collect data only on vehicle trips. The 1990 household travel survey for northeastern Illinois (4) includes trips made exclusively by walking but lumps bicycle trips into the "other" mode category.

Nonmotorized travel models are theoretically different from vehicle models. Vehicle models measure the difficulty of travel as a combination of weighted travel time and cost, which are less meaningful for nonmotorized travel. The decision to make a walking or biking trip and the choice of a destination that can be reached by walking or cycling may have more to do with the safety or attractiveness of available walking or cycling routes than travel time or cost.

## INCORPORATING NONMOTORIZED MODES IN A REGIONAL MODEL

The mode-choice model developed at the Chicago Area Transportation Study (CATS) in the 1970s is an early example of the use of simulation (5) in travel demand models. It simulates the mode choices of individuals using Monte Carlo methods and choice probabilities from a logit mode-choice model. Submodels also employ Monte Carlo methods to determine transit access/egress times and costs, central-area parking costs, and walking distances between central-area parking places and final destinations. In these submodels, a traveler's trip characteristics are selected from zone-level distributions of transit access/egress and parking characteristics.

This simulation approach is extended in a new regional travel model for destination and mode choices. The logic of this regional model is shown in Figure 1. The model simulates nonmotorized destination choice and vehicle versus nonmotorized mode choice in addition to vehicle mode and destination choices.

**Trips with Home Productions**

Trips with an origin or destination at home (trips with a home production) are simulated for all workers, nonworking adults, and children aged 12 to 15 in a single household. These trip simulations are repeated for all households in a small, nonmotorized sub-zone. The simulation continues for all subzones within a larger zone for modeling vehicle travel, and finally it iterates through all vehicle zones in the region. The model simultaneously writes scratch files, which keep track of the destination choices for home-

based (home-work, home-shop and home-other) trips, household characteristics of the worker or nonworking adult, and the mode used to leave home.

**Trips with Work Productions**

Mode and destination choices for all trips with an origin or destination at the workplace, except previously simulated home-work trips, are simulated next. The home-work scratch file is read and tabulated by workplace nonmotorized subzone, worker household characteristics, and home-work travel mode. A workplace trip simulation estimates mode and destination choices for all workers in a subzone, and the program then iterates through all workplace sub-zones and vehicle zones. A scratch file is written to retain the destination choices, worker household characteristics, and mode from work for work-based (work-shop and work-other) trips.

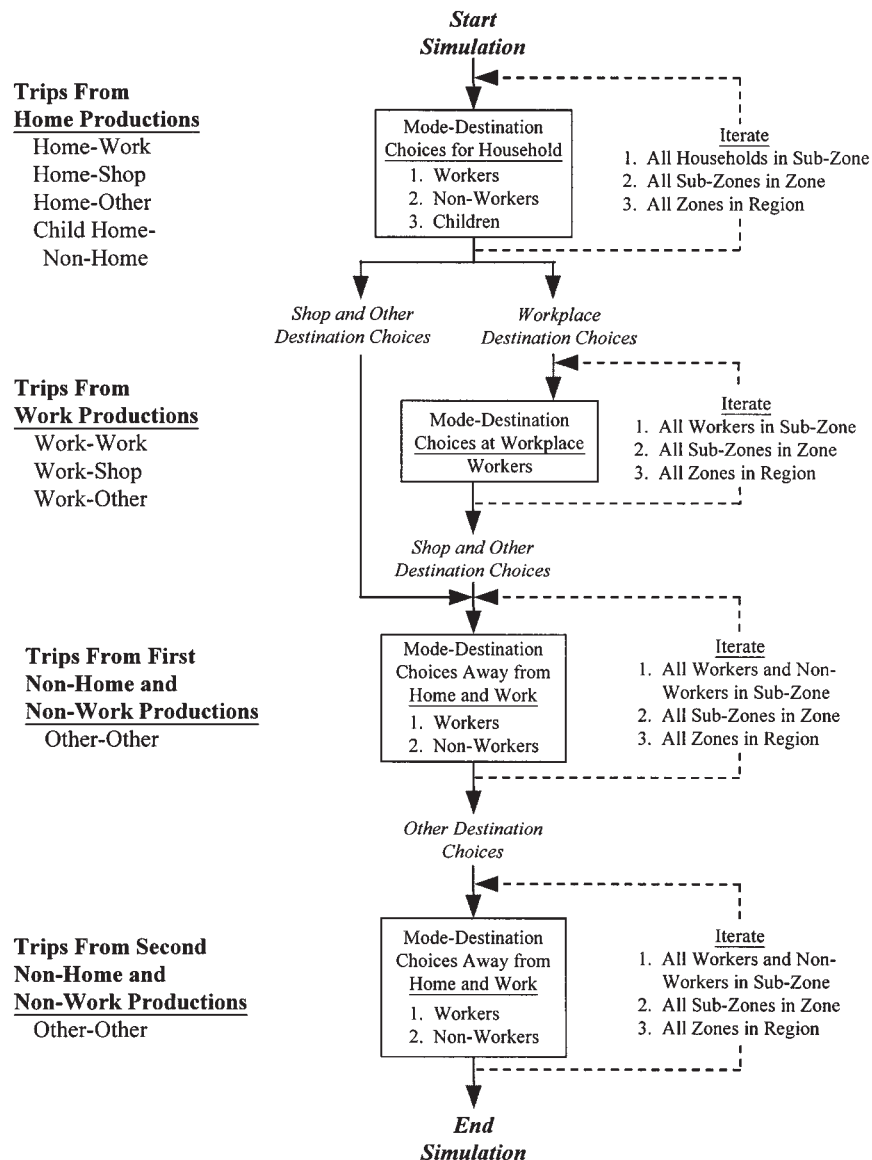


FIGURE 1 Regional simulation model logic.

### Trips with Nonhome and Nonwork Productions

The final trip simulations are for trip productions that are neither home nor work based. The scratch files from worker and nonworker home-shop and home-other trips are read along with the work-shop and work-other scratch files for workers, and tabulated by trip production subzone, worker and nonworker, household characteristics, and previous travel mode. Mode and destination choices for workers and nonworking adults with common household characteristics are simulated following the same approach as home-based and work work-based trips. Scratch files are again written during this simulation, then read for the final simulation of a second round of trips with nonhome and nonwork productions.

### Summary of Model Features

Features of the model shown in Figure 1 that are relevant for modeling nonmotorized trips include the following:

1. Two zone systems are resident within the model. A regional zone system is used for the majority of the vehicle calculations, and vehicle travel times and costs skimmed from the coded highway and transit networks are maintained in matrices matching this zone system. The trip simulations are carried out using a second set of smaller, nonmotorized subzones that can be summarized into the larger vehicle zones. These subzones also are used to determine transit access distances, and they are the zone system in the nonmotorized models.
2. The sequential character of the simulation allows the previously used mode to be considered in nonmotorized versus vehicle mode choice. For example, commuters who do not drive alone to work have a higher probability of work-based nonmotorized travel due to restricted automobile availability at the workplace.
3. A prior destination choice affects the probability of later trips being completed by nonmotorized modes. A worker who commutes to the central area is more likely to make nonmotorized trips from work because the central area is densely developed and pedestrian oriented.
4. The model retains the traveler's household characteristics for subsequent simulations of non-home-based trips. Household composition, income quartile, and vehicle ownership are used as independent variables in the nonmotorized models for trips away from the household.

### Nonmotorized and Vehicle Zone Systems

The two zone systems for northeastern Illinois are shown in Figure 2. There are 1,778 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 on survey townships approximately 9.7 km (6.0 mi) on a side and sections that are roughly 1.6 km (1.0 mi) on a side. Section-sized zones cover the city of Chicago and inner suburbs, with quarter-section and quarter-quarter-section zones in the Chicago central area. Vehicle zones in two outlying Illinois counties and in Indiana are based on census geography because socioeconomic data for these areas are available only in these units.

Although they can barely be discerned in the figure, there are 18,121 nonmotorized subzones dividing the vehicle zones. In the

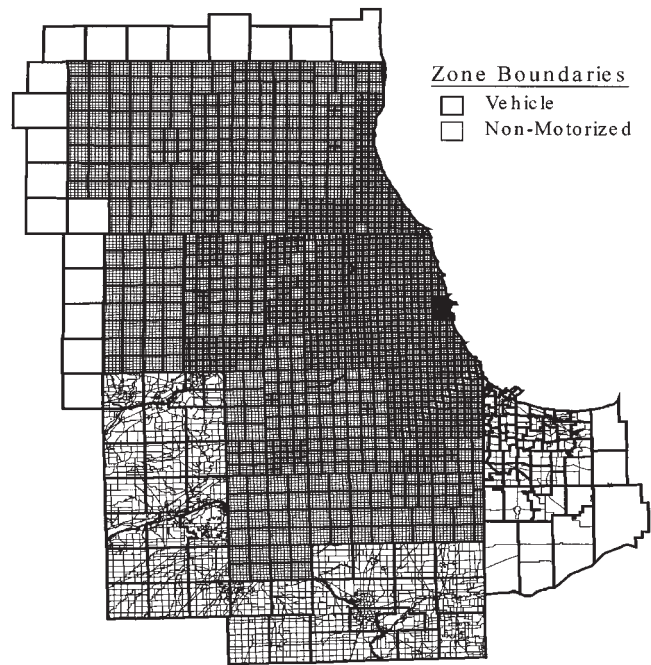


FIGURE 2 Nonmotorized subzones and vehicle zones.

portion of the region where zones follow a regular grid pattern, the nonmotorized zones are quarter sections. Each section-sized vehicle zone, therefore, contains four nonmotorized subzones. In the central area, the nonmotorized zones match the quarter-section and smaller quarter-quarter-section vehicle zones. Nonmotorized zones are formed from census tracts in areas where zones are based on census geography.

### CALIBRATION DATA

Model calibration data sets were prepared from the 1990 household travel survey for nonmotorized destination choice and for nonmotorized versus vehicle mode choice. This survey collected trip data from more than 19,000 households. As noted, walking trips are counted as an explicit mode in this survey, while cycling trips are in the "other" mode category. Fortunately, the other mode is frequently described in the survey data, and most cycling trips can be culled manually from the other category. The household travel survey has trip origins and destinations geocoded to quarter sections matching the nonmotorized subzones.

### Nonmotorized Destination Choice

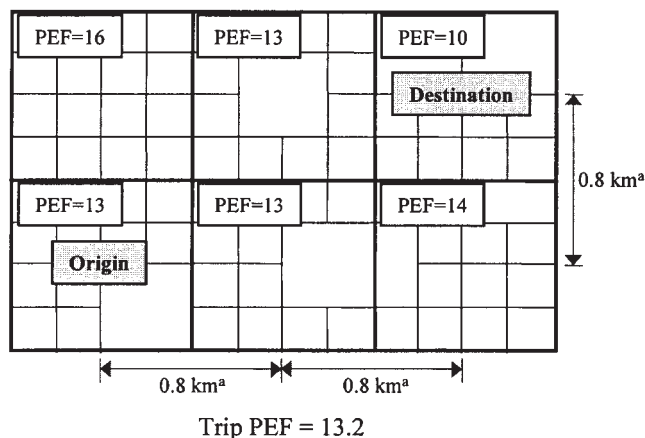
The calibration data set for nonmotorized destination choice is the more complex of the two and is organized as follows. Each observation consists of 50 records for 50 possible destination choices. The first record in an observation is for the quarter section actually chosen as the destination of a nonmotorized trip, and it is created from a nonmotorized trip reported in the household travel survey. The remaining 49 records are for alternative destination quarter sections, ranked by  $X$ -plus- $Y$  distance from the trip origin. The 49 alternative destinations exclude the chosen destination quarter section, but they

may include the origin quarter section when it is not the destination quarter section. These 49 alternative quarter sections encompass all possible destination quarter sections within 3.2 km (2.0 mi) of the trip origin quarter section, even allowing for a few oddly shaped quarter sections. Earlier work showed that the great majority of pedestrian and cycling trips were less than 3.2 km (2.0 mi) in X-plus-Y distance (6), and the nonmotorized destination choice model excludes longer trips.

All quarter-section records contain the same variables, regardless of whether the quarter section is the destination or one of the 49 alternative destination quarter sections:

1. *The X-plus-Y distance between the origin and destination quarter sections.* The X-plus-Y distance is favored over air line distance due to the north-south and east-west orientation of streets in the northeastern Illinois region.
2. *The pedestrian or cycling environment for a nonmotorized trip.* A pedestrian environmental factor (pef) previously was developed at CATS based on the number of census blocks within a quarter section (7). Since census blocks in an urban area include all polygons bounded by streets, this factor measures street coverage. Quarter sections with high pef values generally have adequate local streets for nonmotorized travel. Numerical values of this factor range from the mid-60s in the central business district downward.
3. *One or more variables to measure the attractiveness of the destination quarter section for the type of trip being considered.* For example, retail employment is the variable used to attract home-shop trips.

Figure 3 illustrates how the pedestrian environmental factor (PEF) variable is used to estimate the walking and cycling environment for a nonmotorized trip. The PEFs for the quarter sections within the rectangle formed by the origin and destination quarter sections are simply averaged to obtain the trip PEF. In Figure 3, six quarter sections are inside the origin-destination rectangle. Census blocks per quarter section and PEFs are as shown in the figure and averaged to obtain an overall trip PEF of 13.2. Although the calculation of this factor is directly tied to the township-section geography of the northeastern Illinois region, the method could be tailored to suit the geography of



<sup>a</sup>1 km = 0.6 mi

FIGURE 3 Trip pedestrian environmental factor.

other regions by using census or other small areas rather than quarter sections.

### Nonmotorized Versus Vehicle Mode Choice

The calibration data set for nonmotorized versus vehicle mode choice has a different organization than the calibration data for nonmotorized destination choice. In this data set, there is one record for a trip in the household travel survey. Each record contains a binary variable indicating whether the observed trip is by a nonmotorized or a vehicle mode. The balance of the record has variables describing the household, its size, composition, vehicles owned, and proximity to transit. The final variable is a measure of the composite destination choice utility of the nonmotorized alternative, an accessibility measure reflecting both the quantity of trip attractions that can be reached by walking or cycling and the difficulty of reaching these attractions by nonmotorized modes. It is calculated from the nonmotorized destination choice model as discussed in the following sections.

### NONMOTORIZED DESTINATION CHOICE MODELS

The nonmotorized destination choice models are logit models with the following general form for determining the destination choices of trip productions from any nonmotorized subzone:

$$P_j = \frac{W_j e^{U_j}}{\sum_j W_j e^{U_j}} \quad (1)$$

The probability  $P_j$  of a trip production selecting a subzone  $j$  as a destination when traveling via a nonmotorized mode is estimated by the model. These probabilities sum to 1 for each nonmotorized subzone. The utility associated with a single attraction in subzone  $j$  is  $U_j$ . This utility is estimated as a linear combination of X-plus-Y distance to the attraction's subzone and the trip pedestrian environmental factor. The quantity  $W_j$  is a size variable related to the number of attractions in subzone  $j$ , such as households or employment. In several of the nonmotorized destination choice models,  $W_j$  is a linear combination of two or more size variables.

Model calibration determines the maximum likelihood coefficients for the distance and pedestrian environmental factor in the utility expression. When two or more size variables are in the model, the calibration also estimates the maximum likelihood relative weights for the size variables. The calibration is accomplished with the software package ALOGIT (8). Results of the nonmotorized destination choice model calibration are listed given in Table 1.

As shown in Figure 3, X-plus-Y distance in these models is measured between quarter-section centroids, or 0.8-km (0.5-mi) increments. The trip pedestrian environmental factor also is not permitted to exceed a value of 20.0, since higher values were found to have a negligible effect on model coefficients.

The T ratios in Table 1 show that distance is far more statistically significant in the destination choice utility than the pedestrian environmental factor variable. Coefficients on the pedestrian environmental factor are only marginally statistically significant in the home-other and three work-based models. The  $\rho^2$  quantity in the last column of Table 1 is a commonly used measure of the quality of the

TABLE 1 Nonmotorized Destination Choice Model Calibration

| Trip Production | Trip Attraction | Sub-Zone Utility Variables |           |                       |           | Sub-Zone Attraction Size Variables |        |            |            | $\rho^2$ |
|-----------------|-----------------|----------------------------|-----------|-----------------------|-----------|------------------------------------|--------|------------|------------|----------|
|                 |                 | X+Y Distance               |           | Trip PEF              |           | Employment                         |        |            |            |          |
|                 |                 | Estimated Coefficient      | "T" Ratio | Estimated Coefficient | "T" Ratio | Total                              | Retail | Non-Retail | Households |          |
| Home            | Work            | -2.525                     | -26.5     | 0.159                 | 4.4       | 1.000                              |        |            |            | 0.180    |
| Home            | Shop            | -2.907                     | -28.1     | 0.162                 | 3.6       |                                    | 1.000  |            |            | 0.332    |
| Home            | Other           | -2.600                     | -50.0     | 0.028                 | 1.6       |                                    |        | 0.312      | 1.000      | 0.268    |
| Child Home      | Child Non-Home  | -1.918                     | -17.3     | 0.073                 | 2.2       | 0.521                              |        |            | 1.000      | 0.188    |
| Work            | Work            | -2.757                     | -13.6     | 0.142                 | 1.3       |                                    | 1.000  | 0.150      |            | 0.209    |
| Work            | Shop            | -3.146                     | -11.6     | 0.083                 | 0.5       |                                    | 1.000  |            |            | 0.340    |
| Work            | Other           | -3.898                     | -28.7     | 0.035                 | 0.6       |                                    |        | 0.387      | 1.000      | 0.307    |
| Other           | Other           | -2.884                     | -23.8     | 0.112                 | 2.2       |                                    | 3.080  | 0.266      | 1.000      | 0.297    |

estimated logit model. It is the fraction of the base likelihood explained by the estimated logit model, where a model with zero coefficients determines the base likelihood. Another view of the  $\rho^2$  quantity is that it measures how much of an improvement the estimated model is over a zero coefficient model, which predicts a uniform probability for all destinations accessible by nonmotorized modes.

#### MODELS FOR NONMOTORIZED VERSUS VEHICLE MODE CHOICE

The nonmotorized versus vehicle mode choice models are also logit models, as shown below:

$$P_n = \frac{e^{U_n}}{e^{U_n} + e^{U_v}} \quad (2)$$

This model estimates the probability of selecting a nonmotorized mode for a trip,  $P_n$ . The utilities of the nonmotorized and vehicle choices are  $U_n$  and  $U_v$ .

The composite destination choice utility of the nonmotorized alternative appears as an independent variable in the nonmotorized utility. These accessibility variables are calculated from the destination choice models' denominator:

$$A_n = \ln \left( \sum_j W_j e^{U_j} \right) \quad (3)$$

Remaining variables in the nonmotorized and vehicle utilities and the results of the model calibration are given in Table 2 for trips from home productions. Table 3 has results for trips from nonhome productions. Column headings in the two tables are similar.

The models are stratified by household vehicle ownership for most trip types. The  $\rho^2$  value in the third column measuring the quality of each model is defined differently from the destination choice models'  $\rho^2$  values. A model with zero coefficients does not determine the base likelihood, since this is a poor model that splits trips evenly between vehicle and nonmotorized modes. The base likelihood for the  $\rho^2$  quantities in the tables is the substantially higher likelihood of a model with constant vehicle and nonmotorized utilities. This constant-utility model estimates mode choice probabilities equal to the proportions of vehicle and nonmotorized observations in the calibration data. The resulting mode choice  $\rho^2$  is

generally lower than destination choices  $\rho^2$  because it is more difficult to improve on the mode choice model used to determine the base likelihood.

The remaining columns in Tables 2 and 3 describe the variables in the vehicle and nonmotorized utilities and their statistical significance. Whether the variable positively contributes to the nonmotorized or vehicle utility is indicated, followed by a brief description of the variable, and its estimated coefficient and T ratio. Several binary variables are used in the utilities to indicate proximity to transit, the presence of a worker in the household, and whether an automobile is available for nonhome productions.

The mode choice models for home trip productions have variables describing the availability of vehicle modes. For households without vehicles, a binary variable corresponds to whether transit is located within 0.40 km (0.25 mi) of the household. When the household has one or more vehicles, variables measure the workers or persons in the household competing for a vehicle. The mode choice models for nonhome trips are dominated by binary variables indicating automobile availability at the start of the trip.

#### MODELED AND OBSERVED NONMOTORIZED TRAVEL

Several model runs were completed to prepare nonmotorized trip estimates comparable with observed census and household travel survey data. Home-work nonmotorized trips for 1990 initially were simulated for a 1 percent sample of households and compared against census journey-to-work data (9), which were collected from a 17 percent sample of households, and work trips from the 0.7 percent sample of households in the CATS travel survey. Figures from the census, the household travel survey, and the model are given in Table 4 by city of Chicago and northeastern Illinois county.

Most of the region's nonmotorized home-work travel occurs in Cook County, the innermost county in the region that includes the city of Chicago. Lake and DuPage counties are the most developed of the remaining suburban counties and have the most nonmotorized home-work travel. Lake County figures vary widely because a number of workers live on military bases and are not included in the household survey. The household travel survey and the model generally define trips comparably, but the census journey-to-work data only report the principal mode used for work travel rather than work

**TABLE 2 Nonmotorized Versus Vehicle Mode Choice Calibration: Home Productions**

| Mode Choice Model |                             |          | Utility Variables |   |  |                   |            |
|-------------------|-----------------------------|----------|-------------------|---|--|-------------------|------------|
| Trip Purpose      | Vehicles in Household       | $\rho^2$ | Mode              | Description   | Estimated Coefficient                                    | "T" Ratio         |            |
| Home-Work         | None                        | 0.103    | Non-Motor Vehicle | Non-Motorized Accessibility<br>Transit Within 0.40 km <sup>a</sup> of Home (0,1)                                | 0.539<br>1.917   | 8.5<br>4.6        |            |
|                   |                             |          | Vehicle           | Vehicle Bias  | 5.971  |                   |            |
|                   |                             |          | Non-Motor Vehicle | Non-Motorized Accessibility<br>Adults/Vehicle in Household<br>Transit Within 0.40 km <sup>a</sup> of Home (0,1) | 0.365<br>0.259<br>0.182                                  | 9.7<br>3.5<br>1.1 |            |
|                   | Fewer Vehicles Than Workers | 0.068    | Vehicle           | Vehicle Bias  | 5.750  |                   |            |
|                   |                             |          | Non-Motor Vehicle | Non-Motorized Accessibility<br>Workers/Vehicle in Household   | 0.335<br>2.129   | 11.4<br>6.0       |            |
|                   |                             |          | Non-Motor Vehicle | Non-Working Adults in Household<br>Vehicle Bias   | 0.472<br>9.606   | 6.0               |            |
|                   | Home-Shop                   | None     | 0.029             | Non-Motor Vehicle   | Non-Motorized Accessibility<br>Worker in Household (0,1) | 0.127<br>0.765    | 1.9<br>3.9 |
|                   |                             |          |                   | Vehicle   | Transit Within 0.40 km <sup>a</sup> of Home (0,1)        | 0.421             | 1.4        |
|                   |                             |          |                   | Vehicle   | Vehicle Bias   | 1.446             |            |
| Yes               |                             | 0.132    | Non-Motor Vehicle | Non-Motorized Accessibility<br>Adults/Vehicle in Household  | 0.525<br>0.637   | 18.5<br>10.9      |            |
|                   |                             |          | Vehicle           | Vehicle Bias  | 7.821  |                   |            |
|                   |                             |          | Non-Motor Vehicle | Non-Motorized Accessibility<br>Worker in Household (0,1)  | 0.147<br>0.248   | 5.0<br>1.9        |            |
| Home-Other        | None                        | 0.006    | Vehicle           | Transit Within 0.40 km <sup>a</sup> of Home (0,1)   | 0.098  | 0.4               |            |
|                   |                             |          | Vehicle           | Vehicle Bias  | 2.050  |                   |            |
|                   |                             |          | Non-Motor Vehicle | Non-Motorized Accessibility<br>Adults/Vehicle in Household  | 0.534<br>0.426   | 5.0<br>13.9       |            |
|                   | Yes                         | 0.063    | Vehicle           | Vehicle Bias  | 7.346  |                   |            |
|                   |                             |          | Non-Motor Vehicle | Non-Motorized Accessibility<br>Non-Working Adults in Household  | 0.446<br>0.116   | 9.4<br>1.5        |            |
|                   |                             |          | Vehicle           | Vehicles in Household<br>Vehicle Bias   | 0.074<br>5.031   | 1.1               |            |

<sup>a</sup>1 km = 0.6 mi.

**TABLE 3 Nonmotorized Versus Vehicle Mode Choice Calibration: Nonhome Productions**

| Mode Choice Model |                       |          | Utility Variables |  |                       |              |
|-------------------|-----------------------|----------|-------------------|--|-----------------------|--------------|
| Trip Purpose      | Vehicles in Household | $\rho^2$ | Mode              | Description  | Estimated Coefficient | "T" Ratio    |
| Work-Work         | All Households        | 0.320    | Non-Motor Vehicle | Non-Motorized Accessibility<br>Drive Auto to Work (0,1)                        | 0.530<br>1.853        | 15.7<br>11.7 |
|                   |                       |          | Vehicle           | Vehicle Bias   | 6.620                 |              |
|                   |                       |          | Non-Motor Vehicle | Non-Motorized Accessibility<br>Drive Auto to Work (0,1)                        | 0.679<br>1.809        | 10.8<br>7.4  |
| Work-Shop         | All Households        | 0.429    | Vehicle           | Vehicle Bias   | 6.228                 |              |
|                   |                       |          | Non-Motor Vehicle | Non-Motorized Accessibility<br>Drive Auto to Work (0,1)                        | 0.674<br>1.858        | 22.2<br>18.5 |
|                   |                       |          | Vehicle           | Transit Within 0.4 km <sup>a</sup> of Work (0,1)                               | 0.252                 | 1.9          |
| Work-Other        | All Households        | 0.372    | Vehicle           | Vehicle Bias   | 6.000                 |              |
|                   |                       |          | Non-Motor Vehicle | Non-Motorized Accessibility<br>Previous Mode is Auto Driver or Passenger (0,1) | 0.270<br>1.606        | 3.2<br>3.9   |
|                   |                       |          | Vehicle           | Transit Within 0.4 km <sup>a</sup> of Trip Production (0,1)                    | 1.349                 | 2.8          |
| Other-Other       | None                  | 0.082    | Vehicle           | Vehicle Bias   | 1.967                 |              |
|                   |                       |          | Non-Motor Vehicle | Non-Motorized Accessibility<br>Previous Mode is Auto Driver or Passenger (0,1) | 0.323<br>3.003        | 9.7<br>25.3  |
|                   |                       |          | Vehicle           | Vehicle Bias   | 4.008                 |              |

<sup>a</sup>1 km = 0.6 mi.

**TABLE 4 Observed and Modeled 1990 Nonmotorized Home-Work Travel**

| County          | 1990 Census Journey to Work Mode <sup>a</sup> |         | 1990 Household Travel Survey Trips <sup>b</sup> |         | 1990 Modeled Trips <sup>c</sup> |         |
|-----------------|---|---------|---|---------|---------------------------------|---------|
|                 | Walk or Bike                                  | Percent | Walk or Bike                                    | Percent | Non-Motor                       | Percent |
| City of Chicago | 79,300  | 52.1    | 138,700   | 68.6    | 150,700                         | 61.4    |
| Suburban Cook   | 37,100  | 24.4    | 42,200  | 20.9    | 62,700                          | 25.6    |
| DuPage          | 9,700   | 6.4     | 8,400   | 4.2     | 10,500                          | 4.3     |
| Kane            | 3,800   | 2.5     | 4,100   | 2.0     | 5,200                           | 2.1     |
| Kendall         | 500   | 0.3     | 600   | 0.3     | 0                               | 0.0     |
| Lake            | 16,700  | 11.0    | 4,000   | 2.0     | 12,000                          | 4.9     |
| McHenry         | 2,100   | 1.4     | 2,000   | 1.0     | 2,200                           | 0.9     |
| Will            | 3,100   | 2.0     | 2,200   | 1.1     | 2,100                           | 0.9     |
| Region          | 152,300                                       | 100.0   | 202,200   | 100.0   | 245,400                         | 100.0   |

<sup>a</sup>Principal daily work mode for all workers.

<sup>b</sup>Work trip mode choice for workers living in households.

<sup>c</sup>Work trip mode choice for workers living in households and group quarters.

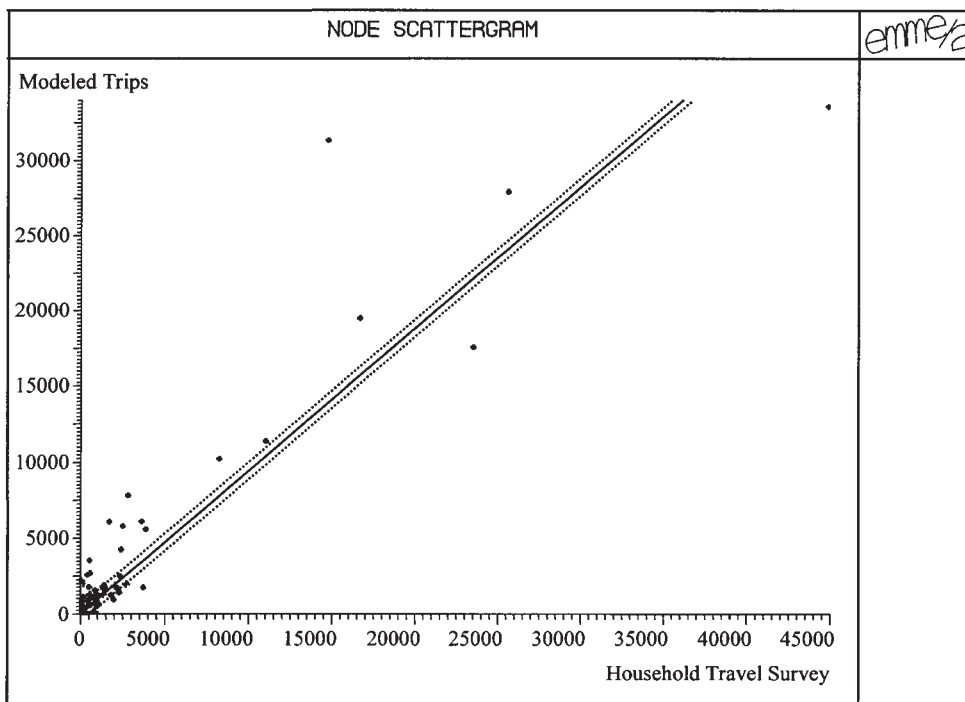
travel for a typical workday. After allowing for these differences in definitions and survey populations, there is reasonable agreement among the modeled trips, the household survey, and the census work-trip data.

**Township Summary**

Household travel survey and modeled nonmotorized home-work trip productions were summarized by townships. Figure 4 shows a scattergram plot of approximately 90 township data points for townships in northeastern Illinois. The plot depicts how well the survey

and modeled nonmotorized trips match at the township level of aggregation. Each point on the figure compares the surveyed nonmotorized home-work trip productions in a township (the horizontal axis) against the nonmotorized home-work trip productions from the model (the vertical axis).

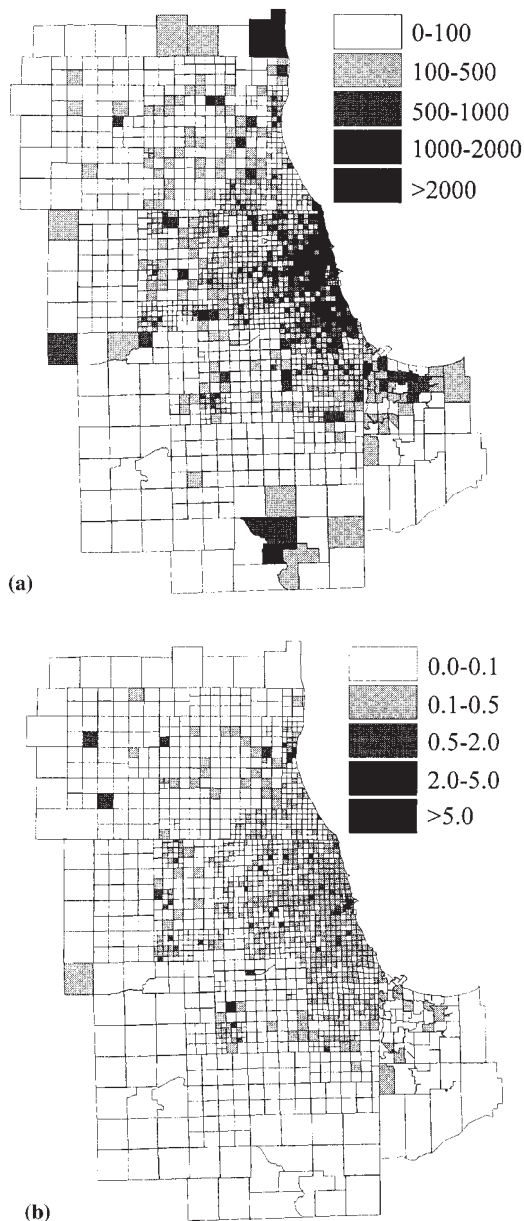
Perfect agreement between the survey and model would yield township data points that fall on a line with a slope equal to one that passes through the origin. A least squares regression line determined from the bivariate township data points is superimposed on the plot. Its slope is 0.93 and it passes through the vertical axis only 32 trips above the origin. The  $r^2$  coefficient of determination equals 0.94, indicating a strong relationship between the two variables.



**FIGURE 4 Home-work nonmotorized trip productions by township, 1990.**

### Modeled Home-Based Nonmotorized Travel by Place of Residence

Home productions (home-work, home-shop, home-other, and child home-nonhome productions) of 1990 nonmotorized trips are shown in the two plotted maps in Figure 5. The top map plots the total nonmotorized home productions in a zone estimated by the nonmotorized models. Since trip density is not plotted, the different zone sizes distort the results. Still, this map's pattern shows nonmotorized trips declining as one moves away from the central part of Chicago. Radial corridors tracing out older established suburbs with better walking and cycling conditions can be discerned in the map. Older fringe cities also feature large numbers of nonmotorized trips.



**FIGURE 5** Modeled nonmotorized home trip productions, 1990: (a) total home-based nonmotorized trips in zone; (b) home-based nonmotorized trips per household.

The bottom map divides the home-based nonmotorized trips by the number of households in a zone, producing a household trip generation rate for nonmotorized trips. These household rates regularly decline as distance from the central city increases. On average, most households in the region generate substantially fewer than one nonmotorized trip per day. The highest nonmotorized trip rates per household (two or more nonmotorized trips per day) are again found in the densest portions of the region.

### FINAL COMMENTS

The methodology described here primarily was developed to evaluate alternative longer-range development scenarios rather than nonmotorized facilities. Changes in the network of nonmotorized facilities cannot be directly tested since the nonmotorized submodels are not network models. However, the pedestrian environmental factor values for specific quarter sections can be adjusted manually when major nonmotorized facilities are proposed, such as several miles of bicycle trail or a pedestrian bridge over a freeway. Many regions will be able to replace or supplement the pef variable and recalibrate nonmotorized models with similar variables from their geographic information systems.

The nonmotorized logit models shown in Tables 2 and 3 can be extracted from the regional simulation model and implemented independently in spreadsheets. These spreadsheet models could prove useful for evaluating proposed pedestrian and cycling facilities. Changes in walking distances and the accessibility of adjacent subzones caused by new nonmotorized facilities can be estimated readily from air photos for a small number of impacted subzones, then entered into spreadsheet models to estimate the gain or loss in walking and cycling trips.

The maps in Figure 5 are comparable with regional maps of vehicle trip data that are routinely prepared by transportation planners. The plots demonstrate that nonmotorized travel can be modeled and forecast as part of the regional transportation planning carried out by MPOs. This capability is a necessity if planning agencies are to evaluate how regional development scenarios affect growth in vehicle travel.

### REFERENCES

1. *Unified Work Program for Transportation: Northeastern Illinois, Fiscal Year 1988*. Chicago Area Transportation Study, June 22, 1987.
2. *Unified Work Program for Transportation: Northeastern Illinois, Fiscal Year 1998*. Chicago Area Transportation Study, June 30, 1997.
3. *Transportation Improvement Program for Northeastern Illinois: FY 1998-2002*. Chicago Area Transportation Study, Nov. 1997.
4. Ghislandi, A. C., A. R. Fijal, and E. J. Christopher. *CATS 1990 Household Travel Survey: Technical Documentation for the Household, Person and Trip Files*. Working Paper 94-04. Chicago Area Transportation Study, April 1994.
5. Gur, Y., E. Lowe, A. Vyas, and E. Ryan. *Urban Modal Split Modeling Using Monte Carlo Simulation*. Chicago Area Transportation Study, 1973.
6. Eash, R. Enhancing Public Transportation and Nonmotorized Modes' Performance in the Regional Transportation Planning Models. *Proc., Metropolitan Conference on Public Transportation Research*, University of Illinois at Chicago, June 1996.
7. Eash, R. Incorporating Urban Design Variables in Metropolitan Planning Organizations' Travel Demand Models. *Proc., Conference on Urban Design, Telecommuting, and Travel Behavior*, Travel Model Improvement Program, Oct. 1996.
8. *ALOGIT Users' Guide: Version 3.8*. Hague Consulting Group, Aug. 1995.
9. *1990 Census Transportation Planning Package: Urban Element Parts 1, 2, and 3. Technical Documentation for Summary Tape*. Bureau of the Census, Sept. 15, 1993.