39-46

ESTIMATING MULTIMODE TRANSIT USE IN A CORRIDOR ANALYSIS

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Experience is needed in the application of mode-choice modeling to detailed submode analysis, model calibration from limited surveys, and corridor-level planning. The paper describes an example of such applications. In addition, the example provides a partial test of previously postulated mode-choice theory. A chain of models based on the utilitarian theory of travel mode choice was used to reproduce and forecast use on competing bus and rail facilities in a suburban Chicago corridor. The models were calibrated by data from a survey area encompassing about a fifth of the study area population. Networks and trip tables were reduced from regional scope for corridor application. The corridor-level analysis allowed inexpensive testing of multiple-design alternatives. Model tests exhibited a satisfactory ability to reproduce data from study area transit rider counts and surveys, including mode shifts related to introduction of the Skokie Swift rapid transit service.

•PREDICTIVE MODELS for forecasting choice of travel mode are now in relatively common use for short-range as well as for long-range planning. Some of these applications involve study areas with inherently competitive transit operations and require analysis at the submode level of detail. At the same time, cost and study time limitations favor model calibration from small data sets if the resultant models can be shown to be reliable. Similarly, present trends favor planning techniques that can be applied to districts, corridors, and other subareas of the region.

These needs place a broad range of demands on the transportation analyst preparing to calibrate and apply mode-choice predictive models. In short, planners are now seeking choice models and procedures that can be applied at the submode level of detail, calibrated from limited data, and utilized effectively for subarea and corridor planning.

In a previous paper by Pratt (2), it was suggested that development of an underlying theory of travel mode choice would be a significant aid in meeting modeling requirements, including needs of this nature. A theory was set forth to the effect that individual choice of mode is utilitarian, that common measures of individual trip utility and choice are subject to chance errors describable by the normal distribution error function, and that deviations result from predictable influences. Some limited applications of the theory were presented, each of them utilizing the modeling technique of describing travel time, convenience, and cost with a single utility measure.

The work described in this paper moves a step forward by involving new application of the theory. Of particular interest is that this added application has involved study of competitive transit services, use of partial survey coverage, and analysis within a single corridor. Thus, the study described has provided experience both in general use of the theory previously described and more specifically in use of the theory for furthering detailed submode analysis, calibration from limited data, and corridor-level planning.

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MODEL REQUIREMENTS OF THE STUDY

Area Description

The work that provides the basis for this case study was performed in the course of a public transportation study for the North Suburban (Chicago) Transportation Council (1). The project was financed by means of a UMTA Technical Studies Grant and by contributions from suburban villages and municipalities. Technical supervision was provided by the Chicago Area Transportation Study (CATS).

The study area covers a band along Lake Michigan roughly 7 miles wide. This corridor extends from the Chicago city limits north past the Cook County line to the Lake County communities of Libertyville and Lake Bluff. Figure 1 shows the study area, its rail services, and the home-interview survey area.

In the corridor, bus transit service is provided by 3 private companies and the Chicago Transit Authority (CTA). Commuter railroad and rail rapid transit service to Chicago is furnished by the Chicago and Northwestern Railway, the Milwaukee Road, and CTA.

In the southern portion of the 7-mile wide corridor, there are 4 roughly parallel rail services to Chicago. These are the Evanston Rapid Transit Line of CTA, the North Line of the Chicago and Northwestern Railway, the Skokie Swift Rapid Transit Shuttle of CTA, and the North Line of the Milwaukee Road. In addition, the Kennedy and Ravenswood CTA rapid transit services terminate close to the southern boundary of the study area.

These various transit alternatives offered to study area commuters differ not only in speed but also in cost, riding comfort, and frequency of service. Needless to say, there is extensive interaction between the private right-of-way transit lines as they affect rider choice.

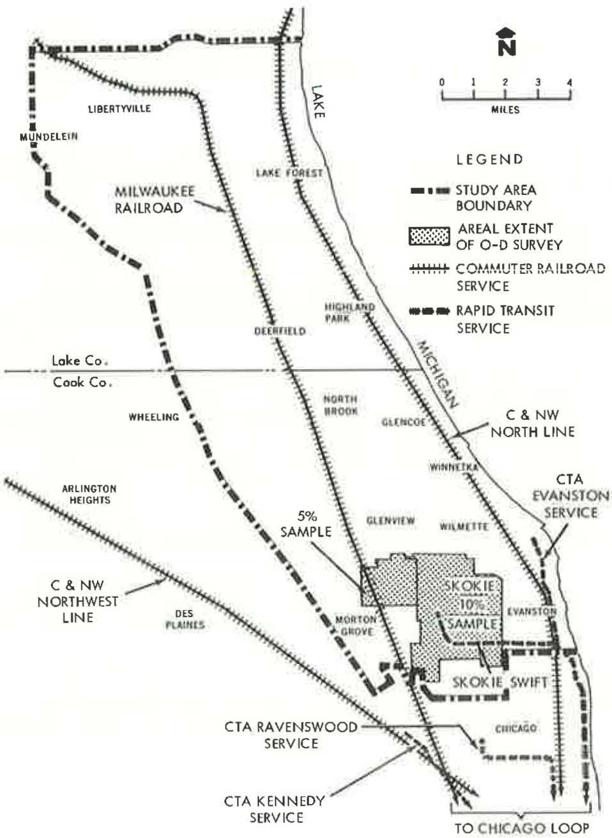

Figure 1. Corridor study area.

Analysis Needs

A high degree of accuracy in the ridership estimates for individual facilities was necessitated by study requirements. One element of the work program called for investigating modifications to the Skokie Swift CTA route, including an assessment of the effect these modifications would have on the parallel carriers. The analysis problem thus was not only to estimate transit ridership but also to allocate it to the correct submode with specific reference to passenger selection of certain competing rail routes.

Use of full regional networks and trip data was obviously not an appropriate strategy for this study. Although the North Shore suburbs form an urban area large in its own right, this same area represents only a small portion of the CATS coverage. Of the 681 CATS traffic analysis zones, less than 15 percent are in the study corridor. Budgetary constraints dictated use of a travel analysis procedure that would not require involvement of the entire CATS system in the calculations. Conversely, the need for local detail favored subdivision of some study area traffic analysis zones.

As discussed in the next section, the study budget also ruled out taking surveys to obtain more travel data than were already available. Given these various considerations and constraints, the objective of the traffic analysis could be summarized as being to accurately estimate transit ridership in a corridor at a minimum cost.

Nature of Survey Data

Within the study area, recent survey data were available only for households within the village limits of Skokie, Illinois, and a portion of Morton Grove. These data had been collected in 1964 in connection with the HUD Skokie Swift and Intra-Skokie Mass Transportation Demonstration Projects. Compared to the study corridor as a whole, the home-interview survey area represented about 7 percent of the land area and a fifth of the population. Within the survey area, a 10 percent sample had been obtained within Skokie and a 5 percent sample within Morton Grove. Complete linked-trip data had been compiled by CATS. Supplemental to the home interview survey were transit rider postcard surveys that served to provide a larger sample for developing submodal choice and mode-of-arrival choice relationships.

The magnitude of survey area and population coverage was about what one might reasonably select given the opportunity to design a limited survey program for determination of study corridor travel patterns and modal-choice characteristics. However, the concentration of survey coverage into a contiguous area was a hindrance. Given the choice, one would obviously subdivide the survey coverage into a number of smaller unconnected areas designed to cover populations with more varied characteristics and travel-choice opportunities.

ANALYSIS STRATEGY

Corridor Analysis Development

The burden of carrying superfluous regional detail through the corridor analysis was removed by combining the traffic zones outside the study corridor and the Chicago CBD into large superdistricts. Concurrently, a number of large zones within the study area were subdivided. The resultant traffic zone system contained only 99 zones. Travel patterns were represented by trip tables compressed and reallocated to this modified zone system. Only trips internal to the study corridor or moving between the corridor and Chicago were retained. Suburban travel involving destinations external to the study corridor was deemed insignificant to transit considerations.

The highway and transit networks adapted for the study were prepared with fairly extensive detail in the corridor area and the Chicago business district. Skeletal network representations of the major facilities were used for the remainder of Chicago. Appropriate pseudo-links were used to represent minor road and feeder transit connections to the superdistrict centroids.

These actions reduced analysis costs markedly as compared to the typical transportation study. The ability to examine multiple plan alternatives in detail was correspondingly increased.

Choice Model Formulation

The choice-modeling strategy adopted was to use a chain of formulations, with each formulation describing the choice between 2 alternative mode categories. All formulations were developed in general accordance with the so-called utilitarian theory of travel mode choice (2). In brief, the pertinent elements of this working hypothesis are as follows:

1. Individual choice of mode is utilitarian. If an individual's unique perception of the travel disutility of each alternative could be measured for a given trip, his choice of mode could be absolutely predicted.

2. Description of individual utility perceptions with standard travel analysis techniques is affected by a multitude of chance errors. These, in sum total, can be described by the normal distribution error function.
3. The probability of free choice of a given travel mode is thus a probability density function of the disutility savings obtainable through use of that mode as compared to the alternate.
4. Deviations result from predictable influences such as captive riding and resistance to long trip length.

Application of the hypothesis makes use of the concept that a single measure can be used to describe travel disutility. The measure used in this study combines time, convenience, and dollar cost into a common unit of equivalent time called the utile. Mathematically, this utile is described as follows: Utile = A × (running time) + B × (walk and wait time) + C × (cost). The coefficients A, B, and C are unknown and must be determined as part of the calibration.

The formulations developed for binary mode selection applied to the following 4 levels of choice:

1. Prime modal split, automobile versus transit;
2. Submodal split, commuter railroad versus other transit;
3. Submodal split, 1 noncommuter transit mode versus another; and
4. Mode-of-arrival split, automobile arrival versus bus or walk arrival at a rail transit station.

Forecasting Model Chain

Study objectives made it desirable to split transit trips moving between the study area and Chicago into 4 submodes. These were commuter railroad, Skokie Swift, other rapid transit, and bus only. Because local trip rail use was minimal, it was decided to limit local trip model application to direct estimation of bus use.

The travel analysis was structured to start with a person trip travel estimate that had been developed from forecasts by CATS. The person-trip estimate was successively split on a trip interchange basis until allocation to the desired submode categories was complete. The sequence followed is shown in Figure 2. As a final adjustment, bus arrival trips were manually segregated from walk arrivals by using a transit station coverage measure.

The interchange impedance measures required by the modeling and forecasting strategy were provided by determining separately the minimum utility transit paths for each of the 3 private right-of-way travel modes. This was done for each private right-of-way mode by removing connections to the transit lines of the 2 modes not under consideration and then building the corresponding network description and minimum paths.

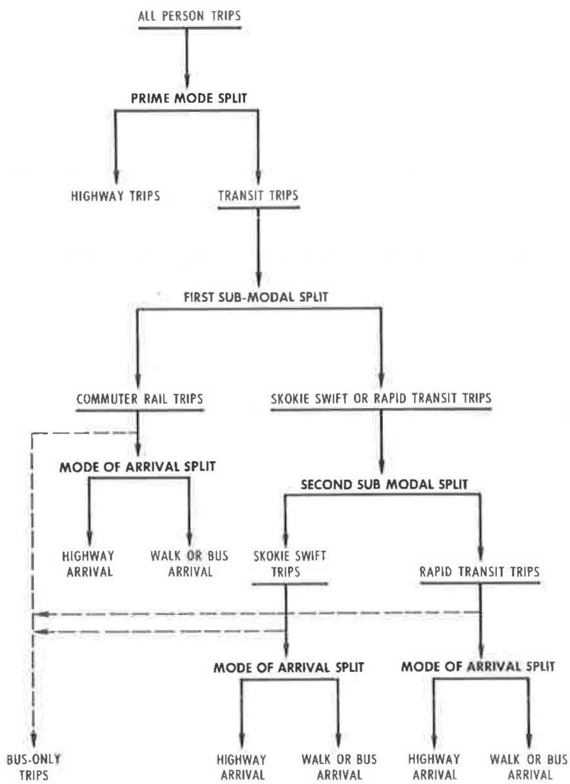

Figure 2. Modal split sequence for commuter travel.

Automobile travel times, operating costs, parking charges, and terminal delays for the prime modal split were obtained in the normal manner.

For travel between the study corridor and Chicago, the "bus-only" trip estimate was accumulated as a residual. All bus lines were retained in each of the 3 transit networks, allowing bus-only paths for interchanges where the mode under consideration was inferior to bus. When trips were split to a path exhibiting no private right-of-way mode travel time, they were automatically assigned to the bus-only category.

Transit networks were coded by using the HUD transit planning programs. For choice-model calibration, the basic travel disutility components were accumulated separately for each of the various modes. However, once model calibration was complete, it was possible to convert all times and costs into utiles by using the equivalent time measure. This allowed the forecast networks to be coded in utiles instead of minutes and the inclusion of all times, convenience measures, and costs.

MODEL CALIBRATION TECHNIQUES

Prime Mode Choice

The prime mode-choice model required by the analysis strategy was calibrated on the basis of observed percentage of home-to-work trips made by transit by residents of the Skokie-Morton Grove survey area. Analysis was limited to interchanges connecting zones of the survey area to attractions in the survey area itself, in Chicago, and in the populous Evanston suburb to the east. The applicable portion of the compressed 99-zone system already described was used except for minor adjustments to match survey coding.

Calibration was facilitated by manually preparing a record for each zonal interchange containing all pertinent interchange information including the number of trips for each mode and the various time and cost measures describing the minimum paths for each mode. The resultant set of records contained all the data needed for model calibration. Computerized versions of this most useful technique have been well described in the literature (3).

Prior to regression analysis, the validity of the proposed formulation was checked by plotting observed percentage of transit versus an initial determination of the difference in disutility among alternative modes. Because at this point the coefficients needed to construct the utile measure had not been determined for the study area, it was necessary to make use of weights developed in previous applications (4). The plotted points did approximate a normal distribution function as anticipated, with the exception that most interchange data, where commuter railroad was the predominant transit mode, showed a higher transit use than would be expected. Commuter railroad travel parameters were subsequently adjusted, as is described later.

The next step was to determine the final weights for computation of the utile. This was done with regression analysis using a modification of the HUD transit planning regression program. Because the model structure is based on the normal distribution error function, application of linear regression required transformation of the dependent variable, percentage of transit. This was accomplished by relating each observed percentage of transit to a standard score, a technique that has been described by Bevis (5). A standard score is the cumulative normal distribution function expressed in values from -281 to +281. Zero percent transit use equates to -281, 50 percent equates to 0, and 100 percent equates to +281.

The first attempt at determining parameter weights used unrestrained regression analysis. This proved to produce mediocre results. A substitute procedure was developed involving use of several trial weight combinations to precompute the utile. Corresponding trial regressions were then run with the following formulation: Percent transit (standard score) = A + B × (transit utiles - highway utiles). Each resultant equation was next identified by its true percentage of error, computed as estimated trips divided by observed transit trips. The percentage of error values were then examined, and the choice was made of those weights that would produce 0 percent error.

The weights chosen for calculation of the utile were 1.0 for running time, 2.3 for walk and wait time, and 3.3 for cost in cents. A final regression equation was then determined for prime modal split as follows: Percent transit (standard score) = 29.2 - 2.76 (transit utiles - highway utiles).

The R statistical measure for this equation is 0.55, which describes the ability of the equation to reproduce the standard score of the observed percentage of transit. This particular R-value computation is not directly comparable to results from other modal-choice analyses.

The phenomena, already mentioned, of higher observed commuter railroad use than would be expected from the network measures appeared to result from 2 effects peculiar to that mode. One effect concerns the waiting time for the train as perceived by the commuter. Study area railroad service frequency is low compared to alternative modes, but schedule adherence is excellent. It was postulated that, for such relatively infrequent but rigidly scheduled transit services, the perceived wait may be less than the calculation used would indicate. Accordingly, the average wait computation for commuter railroad was reduced from a half of the headway to a quarter of the average headway.

The second effect concerned the commuter railroad ride itself. The study area commuter trains, in contrast to the rapid transit cars, have roomy seating, air conditioning, a minimum of center city stops and a seats-for-all policy. Comfort of the ride was taken into account by multiplying commuter railroad travel times by 0.7. These 2 modifications were used in both the modal choice and submodal choice analyses.

Submodal Choice

The augmented travel survey data used in the submodal choice calibration and pertaining primarily to route choice between the Skokie Swift and other rapid transit services had already been used in earlier investigations (6). In the present study, the survey observations were reapplied in accordance with the required modeling structure. The utile measure determined in the prime modal choice analysis was used to develop the following relationship: Percent Skokie Swift (standard score) = -14.68 × (Skokie Swift utiles - rapid transit utiles). The constant term was insignificant and the R-value for the equation was 0.92.

The matter of the constant term is of interest in that the theory behind the model formulations postulates that there should be no constant term for free-choice modal selection. That is to say, at 0 disutility difference, each mode should attract 50 percent of the total travel. In submodal split, captivity to any specific submode should be nonexistent. Thus, the lack of a significant constant term in the submodal regression equation bears out the theory.

In the development of the prime modal choice model, possible automobile and transit captivity (2) was not investigated. Accordingly, the resulting equation cannot be said to pertain exclusively to free-choice riders. For this reason, it is thought that the constant term in the prime modal split equation is caused by captivity effects, primarily the high-income worker captivity to the automobile. Further analysis would be required to ascertain the validity of this presumption.

The available survey data were not sufficient to allow formal calibration of a commuter railroad versus rapid transit submodal split formulation. As a substitute, the rapid transit route choice formula was applied after an adjustment in sensitivity. The adjustment was primarily keyed to terminal relationships in the Chicago business district. The formulation used was as follows: Percent commuter railroad (standard score) = -7.5 (commuter RR utiles - fastest rapid transit utiles).

The mode-of-arrival model was analyzed in much the same manner as the other choice models with the exception that a combined utile measure was not used. The equation for this model was as follows: Percent bus or walk (standard score) = 46.5 - 5.2 (difference of cost) - 4.2 (difference of walk and wait time).

MODEL EVALUATION TEST RESULTS

Three separate tests were conducted of the entire model chain to ensure that the travel forecasting tools being used were adequate for the needs of the study. Two tests involved using the forecasting sequence to prepare estimates of current conditions for comparison with ground counts or similar data. The third test examined the validity of the models under changing conditions. This was accomplished by producing an estimate of riding in the period immediately prior to opening of the Skokie Swift service. In all 3 tests, transit use was estimated for the entire survey corridor.

In the first test, an estimate was prepared of total 24-hour transit use for trips between the city of Chicago and the study corridor. A person trip estimate for 1970 and networks representing existing conditions were used. The resultant assigned volumes were checked against passenger counts. Figure 3 shows the results of a comparison made at Oakton Street, the most southern line in the study corridor where train counts would be free of the local Chicago riding, which was not estimated. Note that the counts were adjusted to remove through riding from beyond the study area.

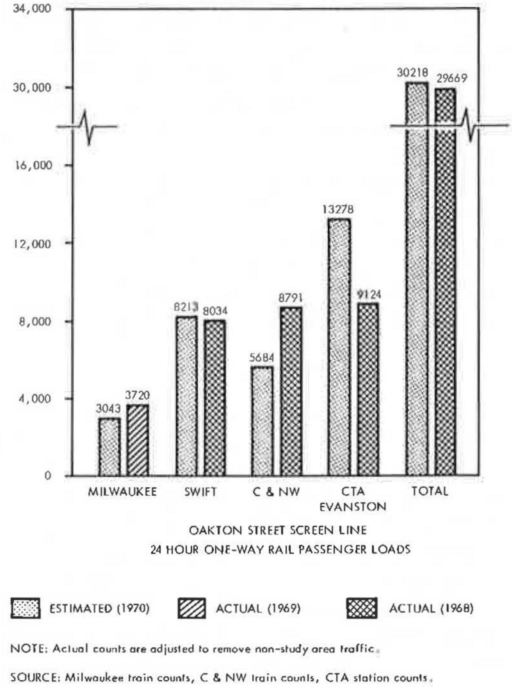

Figure 3. Comparison of synthetic estimate versus actual counts.

The assignment to the commuter rail lines was low, even with the model adjustments made as previously mentioned. On the other hand, both the total screenline forecast and the critical Skokie Swift forecast match counts within 2 percent.

In the second test, estimates of bus use were prepared for each of the suburban bus companies. This estimate was built up from 3 components: estimated bus-only travel between the study corridor and Chicago, estimated bus use for local travel, and estimated bus use for access to rail stations. This test involved all the models and techniques that had been developed. The standard of comparison was average weekday bus revenue passengers. Table 1 gives the results, which show an overall correspondence with 5 percent.

TABLE 1

COMPARISON OF SYNTHETIC BUS RIDER ESTIMATE VERSUS REPORTED PATRONAGE

Bus Company	Weekday Ridership	
	Actual	Synthetic Estimate
Evanston Bus Company	26,486	26,258
United Motor Coach Company	5,697	7,718
Glenview Bus Company	3,125	3,151
Total	35,308	37,127

For the third test, the Skokie Swift line was removed from the transit networks, and the model chain was rerun. The difference in results with and without the Skokie Swift service was then compared with prior mode use data obtained from Skokie Swift riders by postcard surveys in both 1964 and 1966. This test was extremely successful; the prior mode estimate produced by the models fell essentially between the results of the 2 surveys. The comparison is shown in Figure 4.

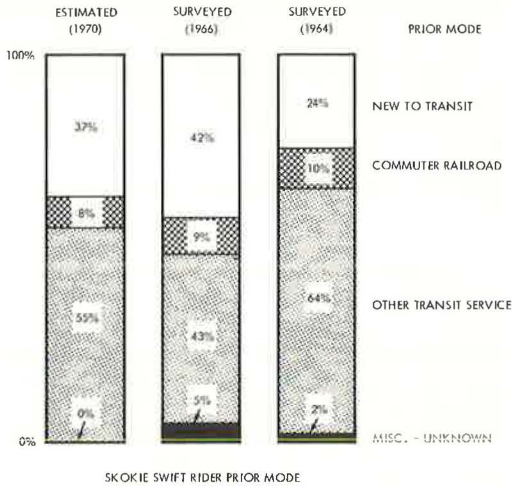

Figure 4. Comparison of synthetic estimate versus survey data.

CONCLUSION

In the example under discussion, use of corridor-level planning techniques and submodal analysis allowed stringent project requirements to be met. The objective of accurately estimating transit ridership at low cost was adequately accomplished with particular reference to estimating shifts in riding associated with modifications to the Skokie Swift. The cut-down networks and trip tables made possible by subarea analysis facilitated inexpensive testing of multiple alternatives.

The calibration of the models from data gathered in a subarea and the subsequent testing and use on the entire study corridor was done from necessity, but the results lent credence to the accuracy of the models.

The difficulties experienced in estimating commuter railroad use and the related understatement of the estimates provided an unexpected degree of statistical support for the importance of amenities such as comfort and schedule adherence. This might be a fruitful area to explore with more extensive survey data.

Perhaps the most significant aspect of the modeling work is that it was accomplished, as has already been discussed, in general conformance with postulated theory. Comparison of results with the hypotheses of the utilitarian theory of mode choice (2) are most encouraging, although it is obvious that a number of theoretical questions remain in need of further investigation. In any case, the techniques of the study described here do appear to make broader application of predictive modeling both feasible and useful.

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