Abridgment

Review of Route-Level Ridership Prediction Techniques

H. ROBERT MENHARD AND GARY F. RUPRECHT

An important trend in the local transit planning field is away from large-scale, capital intensive planning toward low-cost operational planning. Because most major transit and highway facilities are in place, greater consideration is being given to making minor changes to improve the efficiency and increase the capacity of existing transit services. Transit managers need to predict the effect of proposed service changes on ridership for a variety of reasons: (a) to allocate vehicle and manpower resources, (b) to prepare budget requests for proposed service plans, and (c) as inputs into the detailed route planning and scheduling that must accompany new service plans. To perform these tasks adequately, route-level patronage models must be sensitive to service characteristics as well as to the more traditional socioeconomic characteristics of the area the route passes through. The service quality measures most often affected by the route-level service modifications made by most transit properties are headway adjustment, route extension and contraction, limited and express service, shortlining, branching, through routing, creating transfer opportunities, fare adjustments, and new hours of service. A review of techniques that are currently used in the industry for predicting route-level ridership is presented. This review is based on discussions with the planning staffs of 40 transit agencies. Seven criteria were selected for evaluating the various techniques: accuracy, sensitivity, range of application, analyst dependence, cost of application, technical sophistication, and transferability.

Route-level demand models are designed to estimate (a) the ridership along an existing route resulting from service modifications or (b) ridership resulting from the implementation of a proposed new route. In addition, such techniques could be used to project loading characteristics along the route to assure that adequate service capacity is provided.

This review of current modeling practices identified eight types of service changes that use ridership prediction techniques. These changes include

1. New routes,
2. Route extensions,
3. Route cutbacks or eliminations,
4. Changes in service hours,
5. Changes in route alignments,
6. Minor headway changes (5 minutes or less),
7. Major headway changes (over 5 minutes), and
8. Fare changes.

Most agencies that make ridership predictions use them primarily to evaluate, choose among, or justify major changes in their systems. These techniques are seldom used for route cutbacks or eliminations because most transit agencies consider that current ridership is an adequate source of information. Few agencies use modeling or forecasting techniques that can redistribute riders from discontinued routes to alternative routes and modes; instead the tendency is to assume that ridership loss to the system will be equal to the total observed for the route or route segment in question.

Similarly, specific changes in service hours, headways, or minor reroutings are seldom based on ridership predictions. Instead they are typically made in response to observed overcrowding, insufficient loading, passenger complaints, or to comply with changes in policy. Many agencies simply make such changes and evaluate them after they are implemented. Most agencies use ridership predictions only to determine headways and service hours for new routes. In these instances the predictions are used in conjunction with loading standards to determine what service levels will match the demand.

CURRENT PRACTICES

Of the agencies that do predict ridership, most use technically straightforward methods because they require the least time, cost, and technical sophistication. Many agencies are interested only in the potential performance of affected routes in the most general terms. The precision of the ridership estimates often is less important to the agency than having some assessment of the potential success of the new route or route change.

Survey methods are frequently used both by agencies with and without computer support. The processing of more extensive surveys is facilitated by computer support, but many surveys are quite limited (e.g., to a few employers in an unserved area or in the vicinity of a proposed route). Most agencies using statistical techniques have easy if not direct access to a computer and the appropriate software packages, although a few agencies use hand calculators to run simple statistical models. The development of formal models requires a significant level of technical expertise and a relatively large amount of information.

Many agencies use more than one technique to place bounds on the range of anticipated ridership. The approaches range from highly informal to highly complex. A brief description of the four most commonly used techniques follows.

Professional Judgment

Judgmental techniques rely on individual experience with the system and the community served to provide sufficient insight into the problem to make reasonably accurate predictions. There are virtually no restrictions on the types of analyses that can be performed.

Judgmental methods are attractive for a number of reasons. First, they are quick and inexpensive, especially if only readily available data and resources are used. Second, they can be used to analyze virtually any change that a transit agency might consider, as well as the impact of exogenous factors. Because this technique relies on the expertise of the analyst, however, the accuracy of any prediction is highly dependent on the knowledge and experience of the analyst. Even analysts with similar experience may predict significantly different results from the same information. Thus, the transferability of the results is limited.

The widespread use of judgmental methods by transit agencies may indicate that this technique can provide rough estimates and relative rankings needed by these agencies to make decisions about the service they provide.

Noncommittal Survey Techniques

Another conceptually straightforward approach for estimating demand for transit services is the use of the noncommittal survey. In this method, potential riders are asked directly if they would use a proposed service. Their responses to the survey form the basis for predicting anticipated patronage. The approach is called the noncommittal survey technique because of its reliance on the stated intentions of potential riders and not on their actual behavior.

Noncommittal survey methods offer an advantage over judgmental methods because they can provide information to the analyst who has no experience with an area or service change. Of course increased cost comes with this increased information. The survey also presents the opportunity to formalize the manner for analyzing the data thus enabling one service planner to replicate the work of another more easily. As with judgmental methods, the "what if" nature of the surveys used in this technique permits the planner to explore the effects of a wide range of service-related changes. This technique, however, may be limited because the analyst must be able to define clearly the changes of interest. Also, the level of technical sophistication required of the analyst may be higher especially when a large number of surveys and more complex types of analyses are involved.

This technique offers a higher degree of transferability to other situations than judgmental methods because service and population characteristics are obtained through surveys. Its major shortcoming is that the accuracy of ridership prediction relies on the individual respondent's stated intentions. The analyst of the survey results must estimate the likelihood that individuals will act accordingly. As a result, the accuracy of the noncommittal survey technique is to a large extent subject to the same uncertainties as the results of judgmental methods.

Models Based on Cross-Sectional Data

Many agencies find it useful to formalize the prediction of patronage changes by developing mathematical formulas based on characteristics of the route and the type of change being made. These are called cross-sectional models because they address several bus routes and examine the relationship between transit use and level of service, population characteristics, and service areas. The models are based on a comparison between the route under study and characteristics of other bus routes rather than on the effect of changes in a single route over time. Cross-sectional models range from simple comparisons of route characteristics to sophisticated statistical techniques.

The similar routes approach determines which route in a system is most like a proposed new or modified route and then bases the anticipated ridership for the new route on the patronage characteristics of that similar route. The cost of this method can be quite low for agencies that regularly maintain the data needed to classify routes and service areas. The accuracy of the technique is dependent on the service planner's ability to identify correctly a similar route, as well as the major determinants of transit ridership on that route, and to correct for any differences that might exist.

A more formal approach used by a number of transit agencies estimates expected ridership based on established rules of thumb. These rules can be developed from a variety of sources, including the analyst's familiarity with the system, results from other ridership prediction techniques, or from a study done outside the agency. Rules of thumb provide the transit planner with a simple and inexpensive method of predicting ridership along new routes or on new sections of routes. Data requirements are typically limited to readily available sources and the technique can be applied easily by even the most inexperienced analyst at almost any site. Rules of thumb, however, have significant drawbacks, specifically in terms of accuracy and sensitivity to decision variables. For example, these methods are not accurate when estimating the impact of routing and scheduling modifications on ridership when several service attributes are modified.

Multiple factor, trip-rate models represent a more sophisticated form of the simple rule of thumb. This method modifies a basic trip generation rate (based on population) by the factors that account for various levels of service characteristics of the route. Multiple factor, trip-rate models have a wider range of applicability and might be expected to produce more accurate results than simple rules of thumb. Because calibration can be derived from transit data that are regularly maintained, the cost of collecting data and applying the model should not be much greater than for rules of thumb. On the other hand a higher degree of technical sophistication may be required of the user. Also the basic models are generally transferable from one agency to another.

The most common application of formal statistical techniques is regression analysis. Linear regression techniques are used to determine the best mathematical fit between a dependent variable (e.g., ridership) and one or more independent variables (e.g., route or service area characteristics). Models of this sort can be developed to account for a wide variety of decision variables (representing choices open to the service planner) and exogenous factors (e.g., population, gasoline prices, employment, and land use) that directly affect transit patronage. The fact that many exogenous factors and service variables may be included indicates that such models may be applicable over a wide range of situations and may be potentially more transferable than other models. Unfortunately, few results are available for judging the accuracy of these models. Based on theoretical arguments, it appears that the specifications of the existing models leave much to be desired. Lack of a clear causality between independent and dependent variables and the potential for estimating the scheduler's decision rule instead of the response of potential riders to service quality changes are shortcomings found in those models used by transit agencies. From an operational viewpoint, aggregate regression models tend to be more difficult to apply and require a greater level of technical sophistication as well as greater cost.

Models Based on Time Series Data

Another approach to developing models of route-level demand is to estimate the effects of changes based on what happens to ridership on a single route (or group of routes) as service changes over time. These techniques are considered to be based on time series data. An example of such a model is encompassed in what is commonly called the Curtin Rule for the impact of fare changes (1). This model was developed by comparing before and after ridership statistics on a variety of transit systems when a fare change was implemented. This study led to the relationship that for each 1 percent increase (decrease) in the average fare charged, patronage would decrease (increase) by 0.3 percent.

Elasticity methods are a relatively simple form of analysis that can provide quick estimates of the change in ridership that will result from a specified change in the level of service provided along a route. The technique can be applied to a wide range of modifications to existing routes (assuming data are available) but not to predict ridership of new routes. Because the calculations are straightforward, the service planner is not required to have a high level of technical sophistication; and, given the same data, all analysts should obtain the same results. The accuracy of the results from this type of model is dependent on a number of factors, in-

Figure 1. Characteristics of modeling approaches.

	Accuracy[a]	Sensitivity	Range of Applications	Analyst Dependence	Cost of Application	Technical Sophistication[b]	Transferability[a]
Judgment		●	●	○	●	●	
Noncommittal survey		◓	●	◓	○	◓	
Similar routes		◓	◓	◓	◓	●	
Rules of thumb		○	◓	●	●	●	
Trip-rate model		◓	●	●	○[c]	○[c]	
Aggregate regression		●	●	●	○[c]	○[c]	
Elasticity		◓	◓	●	●	◓	
Trend analysis		○	○	●	●	◓	

● better than average; ◓ average; ○ worse than average

[a]Data not available.
[b]Good rating implies a need for limited sophistication: negative rating implies a high degree of sophistication.
[c]Negative rating assumes models would have to be calibrated by the service planner; application of methods requires average cost and technical sophistication.

cluding (a) how the dependent (ridership) and independent variables are affected by other factors and (b) the nature of the demand for transit services (i.e., the shape of the demand curve) and the magnitude of the change in the independent variables.

Sometimes a long-term change in the pattern of ridership may occur because of population growth or a number of other factors. Some transit agencies find it useful to model this underlying trend using a bivariate regression. If the trend is significant, this model can serve as a tool for predicting ridership. Trend analysis can be a useful tool for estimating ridership during periods when service and exogenous factors are not changing or are changing in a consistent manner. Because the technique is not sensitive to service or fare changes, it is not useful in most route planning contexts. The technique is inexpensive and relatively simple to use. It requires little more than a calculator with statistical capabilities--an estimate could be obtained by manually plotting the data.

CONCLUSION

Most transit agencies recognize the need to predict transit patronage at the route level and have adopted one or more techniques to perform such analyses. Yet, despite the widespread use of route-level demand models, few agencies can quantify the accuracy of their models or explain the contribution they make to planning processes. Most of these models are simplistic, easy to apply, and rely on minimal data; thus, they yield only ball-park ridership estimates. On the other hand, some techniques attempt to reflect the processes underlying the generation of transit ridership. A number of researchers have developed formal statistical models that account for a variety of factors that may affect ridership and have incorporated the effects of a number of decision variables available to the bus service planner. Unfortunately no existing model is totally adequate for the planning function; all have drawbacks and few have been shown to be accurate through before and after experimentation.

This review does not indicate that a single model or type of model is significantly better or more useful than any other model. Figure 1 illustrates the advantages and disadvantages of each approach. It does, however, illustrate the need for additional evaluations of specific models to determine their range of accuracy. In addition there appears to be a need to alleviate many of the theoretical drawbacks of the models being used.

ACKNOWLEDGMENT

The research reported in this paper was performed with funding from the U.S. Department of Transportation, Urban Mass Transportation Administration.

REFERENCE

1. J.F. Curtin. Effects of Fares on Transit Riding. HRB, Highway Research Record 213, 1968, pp. 8-18.

Publication of this paper sponsored by Committee on Public Transportation Planning and Development.