Abridgment

Note on Bus Route Extensions

Daniel K. Boyle

This paper investigates the circumstances under which extensions of bus routes can be feasible. Ten recent route extensions in Albany and Rochester, New York, are examined with respect to ridership generated, length and frequency of service, type and size of the new population served, and additional operating cost. The extensions included extensions to new residential and industrial sites, reverse commute services, and services to major employment sites. A simple revenue/cost ratio for bus route extensions is used to compare the results. The paper concludes that route extensions that are most likely to be successful (a) are short, (b) serve a dense area of concentrated employment or residences, and (c) do not increase main-route headway.

Decisions on proposals for route extensions are generally made on an ad hoc basis because no criteria have been developed to guide the decision-making process. A few transit operators have set standards, which involve measures such as passengers per vehicle kilometer or revenue/cost ratio, that must be met within a certain period of time if a route extension is to be made permanent (1). Some areas have used relatively sophisticated measures (such as transit access time) to serve as a basis for service decisions. Others use analogies to similar areas where transit service already exists to judge whether a route extension is justified. Often, the results are less than satisfactory; route extensions are frequently abandoned because the ridership does not materialize.

Ideally, a cost/benefit model could be constructed and used to determine the relative merit of any route-extension proposal. This report is a first step in that direction. Four route extensions in the Albany, New York, area (Capital District) and six extensions in Rochester, New York, are examined to see how different areas respond to improved access to public transit. This study gives a preliminary indication of which types of extensions are most efficient in terms of benefit/cost analysis. It also provides a basis for development of a route-extension model.

DATA

Of the 10 route extensions, 4 served new residential developments and 2 routes were extended to hospitals, 1 to an industrial park, and 1 to a commercial area. The remaining 2 extensions were taken as efficiency measures to make routing patterns or turnaround at the end of the route more convenient.

Seasonally adjusted ridership data were readily available for all routes. Three routes had headway changes associated with the route extensions. In these cases, appropriate service elasticities (2) were applied to determine the ridership change due to change in service along the original route. This change was subtracted from the change in total route ridership to arrive at the ridership change associated with the route extension.

Data on households, population, employment, and land area were collected by traffic analysis zone (TAZ). Most extensions involved only one zone, but in certain cases data for two or more zones were needed. Table 1 presents ridership and demographic information for each route extension.

The heavy ridership loss on route 80 demonstrates how outside factors can overshadow minor changes in ridership that result from route extensions. An extension to a hospital in Rochester had no effect on ridership, but a significant increase in ridership resulted from a similar extension in Albany (although the Albany extension served an established residential neighborhood as well as a hospital). A significant industrial employment area shows the same ridership response as a minor commercial employment area. Ridership increases in residential areas do not match up well with population or population density.

The size of the analysis zones may explain the lack of consistent trends. Although preferable to census tracts, these zones still encompass a larger area than is actually served by the extensions. The extensions are targeted for specific developments; a measure of population and employment on a smaller scale would be more conducive to analysis of the relationship between transit ridership and various demographic figures.

Information concerning income, number of automobileless households and the like can, in all probability, aid in explaining different responses to route increases in otherwise demographically similar areas. At the current time, the socioeconomic data base in the Capital District and Rochester is incomplete, but further research should yield fruitful results.

The data obtained for route extensions are sufficient to determine revenue and cost changes. A revenue/cost ratio (R/C) can be calculated as follows:

$$\Delta R/\Delta C = (\Delta \text{ ridership} \times \text{ average fare})/(\Delta \text{ vehicle kilometers} \times \text{ average operating cost per vehicle kilometer}) \qquad (1)$$

Changes in both ridership and vehicle kilometers were calculated for an average weekday. In calculating revenue, \$0.40 was used as the average fare in the Capital District (where \$0.40 is the base fare) and Rochester (average of peak and off-peak fares). For park-and-ride express routes, an average fare was estimated based on the fare structure.

Average operating costs per vehicle distance traveled were obtained for the Capital District and Rochester areas from the latest transit operating assistance report (3). In Rochester, average operating cost was \$1.13/vehicle-km (\$1.81/vehicle mile); the Capital District figure was \$0.86/vehicle-km (\$1.38/vehicle mile). These averages overestimate the actual cost of operation in the route-extension area because most extensions are in outlying areas where average speed is higher; therefore, the operating cost per vehicle kilometer is lower than the systemwide average. However, the degree of inaccuracy introduced by the use of average operating cost per vehicle kilometer is slight and is outweighed by the ease of calculation.

REVENUE/COST ANALYSIS

The results of the R/C calculations are presented in Table 2. Of the 10 extensions, 4 showed a $\Delta R/\Delta C$ ratio greater than 1.00, which indicates that these not only paid for themselves but showed a profit. Two of the four profitable route extensions occurred on park-and-ride routes and were targeted for employee concentrations. The PR 2 extension served a reverse-commutation demand by bringing workers to a surburban office location from Rochester. The PR 1 and 2 extensions provided service within a major industrial park, thus eliminating a long walk for transit patrons.

Table 1. Route extensions, ridership, and demographic data.

Route Number	Length of Extension (km)	Δ Average Weekday Ridership	Population in TAZ	Household Density in TAZ (households/ km^2)	Employment Density in TAZ (employees/ km^2)	Purpose of Extension
Capital District						
80	1.1	-599	1 900	277	37	Convenience
82	0.8	2	2 010	423	91	Residential
84	3.2	105[a]	10 077	1184	2103	Hospital and residential
89	1.6	142[a]	4 965	314	353	Residential
Rochester						
21	1.6	40	831	62	65	Residential
PR2	1.1	40	732	59	74	Commercial
3	1.1	0	5 916	519	348	Hospital
4	0.6	2[a]	4 353	692	153	Convenience
PR 1 + 2	4.2	40	4 704	647	6983	Industrial
RIT	0.4	50	1 005	49	178	Residential

Note: 1 km = 0.62 mile; 1 km^2 = 0.39 $mile^2$.
[a]Adjusted to take headway changes into account.

Table 2. Revenue/cost ratios for route extensions.

Route Number	Δ Ridership	Δ Revenue ($)	Δ Vehicle Kilometers	Δ Operating Cost ($)	ΔR/ΔC
Albany					
80	-599	-239.60	59.4	51.20	-4.68
82	2	0.80	19.2	16.56	0.05
84	105	42.00	57.6	49.68	0.85
84[a]	31	12.40	-70.0	-53.00	-0.23
89	142	56.80	20.8	17.94	3.17
Rochester					
21	40	16.00	35.2	39.82	0.40
PR2	40	26.00	2.3	2.57	10.12
3	0	0.00	8.6	9.70	0.00
4	2	0.80	68.6	77.65	0.01
PR 1 + 2	40	40.00	8.4	9.45	4.23
RIT	50	20.00	4.2	4.71	4.25

Notes: 1 km = 0.62 mile.
All data measured for an average weekday.
[a]Taking into account effects of associated headway changes on existing portion of route.

The RIT and route 89 extensions served residential areas; it is hypothesized that certain socioeconomic variables in the extension area can account for the success of these extensions. Local conditions might also account for different responses to extensions. For example, the route 89 extension improved transit access in an area that had a significant concentration of public housing and no sidewalks. Previously, it had been very difficult to walk the distance to the bus stop; the extension brought service to a large pool of likely transit users. Knowledge of such local conditions is both useful and necessary in judging the relative merits of a specific extension.

A general R/C model of the form of Equation 1 is suggested for use in evaluating route extensions. In cases where extensions have been put into effect, use of this model is straightforward. For potential extensions, a method must be developed for estimating changes in ridership. This might be of the form:

$$R = p \times f(a) \quad (2)$$

where p is the pool of potential transit users (e.g., number of residents in a new housing development or number of workers in an industrial park) and f(a) is an attraction function dependent on socioeconomic data and quality of service. Different f(a)'s could be developed for different land use areas. With such functions, the feasibility of a route extension in a given area would depend on the size of the potential transit pool, relevant socioeconomic data, the length of the extension, and the quality of service offered.

The model allows for calculation of R/C ratios; however, criteria for judging the success of a route extension is subjective. A profit criterion would stipulate that the route extension be taken if ΔR/ΔC is greater than or equal to 1.0. Alternatively, an equal subsidy criterion might suggest that the route extension be taken if ΔR/ΔC for the extension is greater than or equal to the R/C ratio for the existing route or if ΔR/ΔC for the extension is greater than or equal to the R/C ratio for the entire transit system.

SUMMARY AND FUTURE DIRECTION

It is clear that the success of route extensions depends heavily on the character of the area to which the extension is made. Land use, population, population density, income, and number of automobileless households are some of the variables hypothesized to be salient in determining the response to a route extension.

The census tract or the traffic analysis zone is too large to be used as the geographic base for the collection of demographic data. Since most extensions are targeted for a specific residential development or employment concentration, demographic data are needed on an approximately small scale.

The form of the R/C model indicates that, in similar land use areas, the success of a route extension depends directly on the size of the pool of potential transit users and inversely on the length of the extension. Obviously, a short extension to an area that has a large residential or employment population is most efficient in terms of the R/C ratio.

In cases where headway on a given route must be increased due to an extension of the route, the decline in level of service along the original portion of the route serves as a counterbalance to the new service on the route extension. The quality of service may decline along with the quantity of service as the original portion of the route becomes more crowded. For route extensions that have corresponding headway increases, the riders on the existing route are in effect subsidizing the extension through a decline in service on the original portion of the route.

Four of the 10 route extensions showed an R/C ratio greater than 1.0. An examination of each of these successful extensions highlights various factors discussed previously.

The PR 2 extension had the highest $\Delta R/\Delta C$. This extension was made to a commercial area in order to serve reverse-commutation trips from Rochester. This extension of an express park-and-ride line was the only 1 of the 10 extensions to serve a commercial area. It has been suggested that high-quality transit service at a high price is most likely to be self-supporting.

The PR 1 and PR 2 extension into Kodak Park also proved to be profitable despite the fact that it was the longest of the 10 extensions. The previous comment concerning high-quality service is also applicable here. Extensions to areas of significant employee concentration appear to be most promising in terms of R/C ratio.

The RIT extension to a residential area was the shortest of the 10 extensions. This demonstrates the importance of the length of the route extensions.

The route 89 extension brought service within easy reach of public-housing residents, many of whom are captive transit riders. Local factors also contributed to the positive ridership response to this extension.

In conclusion, size of population, type of land use, quality of service, and length of extension are four major factors in the determination of the success of route extensions. Areas that have a significant concentration of employees seem most likely to support profitable extensions. Special local conditions can also influence ridership changes connected with route extensions. A general R/C model can be used to evaluate route extensions, and the criteria used to judge extensions can be left to the discretion of local operators. The problem of increased headways associated with route extensions resulting in a decline in service on the original portion of the route must be taken into account when it arises. Finally, conventional units of data collection (such as census tracts or TAZs) are too large for the purpose of evaluating route extensions.

Directions for further research in the area of route extensions are clear. Collection of data on a small scale commensurate with the area actually served by an extension and explicit correlation of these data with changes in ridership are the immediate next steps to be taken. The development and testing of attraction functions for different types of land use follow these steps. A general predictive model of the effects on transit ridership of route extensions can then be constructed. This paper has suggested the basics for such a model and has provided preliminary findings concerning the most salient factors in determining the outcome of a proposed route extension.

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Hierarchical Procedures for Determining Vehicle and Crew Requirements for Mass Transit Systems

Lawrence D. Bodin and Robert B. Dial

This paper presents procedures for determining vehicle and crew requirements for mass transit systems. Some of these procedures are very fast computationally but only give lower bounds, upper bounds, or estimates of resource requirements. Other procedures are slower computationally but give actual crew and vehicle schedules. Depending on the type of analysis being performed (long-range planning, short-range planning, or operational planning), all of these procedures play a useful role in the design and analysis of proposed mass transit systems. The paper has two sections: (a) the first discusses techniques for determining vehicle requirements and (b) the second discusses techniques for determining crew requirements. Within each section are a set of procedures that range from the very simple to the complex, along with comments on their usefulness and shortcomings.

The design of mass transit systems occurs in various planning scenarios: long-range planning (5-20 years in the future), short-range planning (1-5 years in the future), and operational planning (less than 1 year in the future). The long-range planning analyst does not need (and cannot afford) the same information on crew and vehicle requirements as the operational planner. Whereas the operational planner needs actual feasible crew and vehicle schedules, the long-term planner may only need an estimate or lower and upper bounds on total crew and vehicle requirements for the analysis. Thus, the long-range transit planner should use fast crude estimation procedures to help evaluate a proposed transit system, since he or she may consider scores of alternative transit systems in attempting to find the optimal system.

In this paper, hierarchical procedures for determining crew and vehicle requirements are given. Some procedures require only manual calculations and furnish inexpensive (albeit crude) estimates. Others consume a significant amount of computer time and give more accuracy and detail. As will be seen, if the planner requires a more exact or more detailed vehicle or crew schedule, a higher cost must be absorbed in terms of computer time and human effort.