Estimating Transit Supply Requirements for Alternatives Analysis

ROBERT E. SKINNER

The estimation of transit supply parameters has received relatively little attention in the technical literature. Yet these supply parameters, such as vehicle miles, vehicle hours, and employees by category, are the major determinants of operating cost estimates that, in turn, are a principal factor in evaluating major transit alternatives and selecting a single alternative for implementation. Furthermore, it is during the estimation of transit supply parameters that basic questions of operating feasibility are addressed, implicitly or explicitly. Through the use of a simple example for a single rail line, the complexity of supply-parameter estimation is illustrated in terms of the number of assumptions and inputs required. The example also illustrates the sensitivity of the supply-parameter estimates to variations in input assumptions. A framework is presented for the process of supply-parameter estimation in context with the overall transit planning process, particularly with respect to federally required alternatives analysis studies. Some general considerations in the use of this process that are discussed include the need for supply-demand equilibrium, the iterative nature of the process, the differences between phase 1 and phase 2 alternatives analysis studies, operating feasiblity, and the relation between predictive techniques used in supply-parameter estimation and "reasonability" checks. Finally, selected examples of specific inputs to the process are discussed and recommendations are made with respect to how these inputs should be developed. The examples include vehicle capacities and loading standards, service hours and service days, background bus networks, special services, and demand estimates.

Supply-parameter estimation has received relatively little attention in the technical literature. Certainly, in comparison with demand estimation, there is a paucity of formalized procedures and technical guidelines for the estimation of supply parameters. In transit planning studies, supply-related assumptions and procedures are sometimes made or selected in ways that are inconsistent between alternatives (e.g., passenger capacity of buses versus rail cars) or that do not fully take into account their impact on aggregated supply parameters and operating costs. Distortions resulting from such practices are particularly serious if they occur in federally required alternatives analysis studies whose intent is to determine the worthiness of major capital investments in new transit facilities.

In the context of this paper, transit supply parameters are those measures that describe and quantify either (a) the amount of transit service a given alternative will provide or (b) the nonmonetary resources needed to maintain this level of transit service, such as vehicles or employees. The following key supply parameters are considered in this paper:

1. Peak-period daily and annual vehicle (train) hours by vehicle type,
2. Peak-period daily and annual vehicle (train) miles by vehicle type,
3. Fleet size by vehicle type,
4. Employees by category,
5. Peak-period daily and annual place hours by transit mode,
6. Peak-period daily and annual place miles by transit mode, and
7. Average system operating speed by transit mode.

Supply-parameter estimation is an important component of alternatives analysis studies because supply parameters are key inputs to operating-cost estimation and to the determination of operating feasibility. The topic of transit supply-parameter estimation is far too broad to be fully addressed in this paper. Instead, the paper presents selected topics drawn from alternatives analysis research undertaken for the U.S. Department of Transportation (1) that provide some overview discussion of supply-parameter estimation as well as specific guidance for planners on some key issues.

EXAMPLE

To illustrate the sensitivity of supply-parameter estimates to input assumptions and procedures, an example is helpful. The assumptions and procedures used to estimate three key supply parameters for a hypothetical rail line--annual train hours, annual car hours, and annual car miles--can be summarized as follows. The alternatives used are defined as

1. A 10-mile rail line with seven stations;
2. Average station spacing of 1.67 miles;
3. The following vehicle characteristics: (a) 630 gross ft^2/car, (b) maximum train consist of three cars, (c) loading standard of 5.4 ft^2/passenger, (d) cruise speed of 60 mph, and (e) service acceleration and deceleration of 3.0 mph/s;
4. Policy headways of 5 min for the 4 peak hours and 10 min for the 12 off-peak hours;
5. Weekend and holiday service resulting in an annualization factor of 310;
6. Station dwell time of 40 s; and
7. Minimum headway of 2.5 min.

The following demand levels are used:

1. Maximum-load-point volume--32 000 riders (two ways),
2. Peak-hour, maximum-load-point volume in the peak direction--4800 riders (15 percent of total ridership), and
3. Off-peak, maximum-peak-load-point volume in the peak direction--1200 riders (3.75 percent of total daily ridership).

The procedures used to estimate supply parameters are as follows:

1. Average speed estimated by using a formula applicable for sufficient station spacing to reach cruise speed (2):

$$S = D/[T + D/C + C(1/2a + 1/2d)] \quad (1)$$

where

S = average transit vehicle speed,
D = average distance between stations,
T = stop time at stations or stops,
C = cruising speed,
a = rate of acceleration, and
d = rate of deceleration;

2. Train hours minimized (headways maximized) subject to policy headway and demand constraints;
3. Adequate capacity provided in 12 off-peak hours to meet peak-load-point, peak-direction demand (1200 riders/h); and

4. Adequate capacity provided in 4 peak hours to meet peak-load-point, peak-direction demand (4800 riders/h).

The baseline estimates for these parameters and their sensitivity to various changes in assumptions or procedures are given in Table 1.

Because additional passenger capacity can only be added in discrete units, excess capacity is usually provided in order to meet a prespecified demand level. The amount of excess capacity provided influences the degree of change in supply parameters that may occur in response to a change in an input assumption. Consequently, Table 1 also indicates the amount of peak and off-peak excess capacity provided by each sensitivity test.

Based on this example, several observations can be made about the estimation of supply parameters:

1. The sheer number of input assumptions alone illustrates the complexity of supply-parameter estimation. The example is really not so "simple" after all. Furthermore, the need for decision rules, such as minimizing train hours, suggests that the procedures are not as straightforward as many have supposed.
2. Because of the "lumpiness" in the supply curve, a minor change in a particular input parameter (such as cruise speed) may sometimes be just enough to reduce equipment requirements. At other times, however, a more substantial change in an input parameter may have a negligible impact. The net change depends in part on site-specific circumstances (thus, it is not possible to generalize based on the results of this example).
3. None of the sensitivity tests revealed dramatic changes in supply parameters resulting from a single change in an input assumption over the ranges tested. They do illustrate, however, that seemingly insignificant assumptions can constrain or partly predetermine results--for example, peak-hour peaking factors, station dwell times, annualization factors, and off-peak policy headways.
4. The impact on supply parameters of multiple changes in input assumptions can be additive so that, instead of 5-10 percent changes, 30-40 percent changes in supply parameters might result. For example, the combination of tests 6 and 10 decreases train hours by 35 percent. Two different sets or packages of assumptions could yield very significant differences in supply-parameter estimates.
5. Train hours, probably the most significant parameter from the standpoint of operating cost, tended to be more sensitive to changes in input assumptions than either car miles or car hours.
6. Changing the objective function from minimizing train hours to minimizing car miles can result in significant changes in supply parameters.

GENERAL CONSIDERATIONS

The following section of this paper first describes, in conceptual terms, the process of supply-parameter estimation and how it relates to the overall planning process for alternatives analysis studies. Next, it discusses critical general considerations that relate to the estimation process as a whole.

Process of Supply-Parameter Estimation

Figure 1 shows schematically the process of supply-parameter estimation and how it relates to other steps in the overall alternatives analysis process. Key inputs to supply-parameter estimation are the definition of alternatives (step 1) and ridership forecasts (step 2). For the most part, supply-parameter estimation takes place in steps 3, 4, and 5. The resulting supply-parameter estimates serve as input to the estimation of transit operating cost (step 6) and, to a lesser extent, the estimation of capital costs.

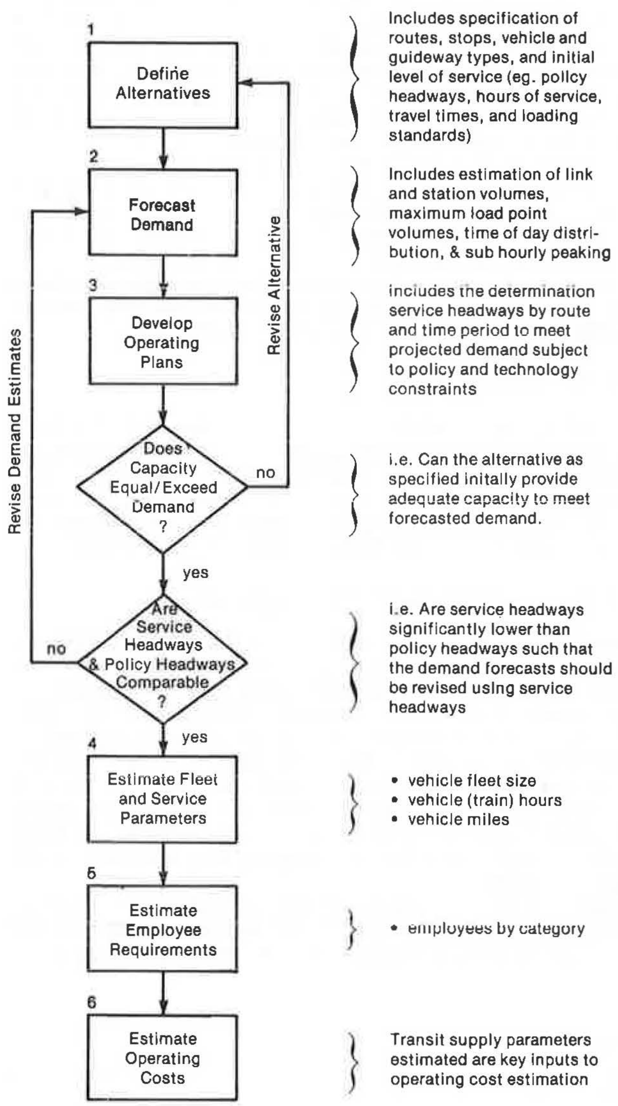
Definition of alternatives includes an initial specification of the level of service (LOS) to be provided by each alternative. Based in part on this

Table 1. Sensitivity of supply parameters to changes in analysis assumptions and procedures.

		Cars Required[a]		Annual Supply Parameter[b]: Train Hours		Car Hours		Car Miles		Excess Capacity (no. of passenger places)	
Test No.	Sensitivity Test	No.	Change[c] (%)	No.	Change[c] (%)	No.	Change[c] (%)	No.	Change[c] (%)	Peak	Off-Peak
1	Baseline estimates	24		24 784		59 483		2 232 000		465	555
2	Decrease loading standard by 10 percent to 4.9 ft^2/passenger	21	−12.5	23 537	−5	55 741	−6	2 090 640	−6	309	555
3	Increase cruise speed by 10 percent to 66 mph (increases average speed by 4 percent)	21	−12.5	23 498	−5	55 645	−6	2 184 260	−2	9	632
4	Increase maximum train consist to four cars	24	0	24 784	0	59 483	0	2 232 000	0	465	555
5	Decrease annualization factor by 10 percent to 279	24	0	22 306	−10	53 535	−10	2 008 800	−10	465	555
6	Remove one station and increase average station spacing to 2 miles, or +20 percent (increases average speed by 18 percent)	21	−12.5	19 809	−20	48 267	−18	2 145 510	−4	641	361
7	Decrease station dwell time to 30 s, or −20 percent (increases average speed by 7 percent)	21	−12.5	19 809	−20	48 298	−18	1 935 950	−13	114	206
8	Decrease maximum train consist to two cars	22	−8	28 463	+15	56 926	−4	2 137 760	−4	25	555
9	Decrease peak-hour, peak-load-point, one-way volume from 15 to 14 percent of daily, maximum-load-point, two-way volume (from 4800 to 4400 passengers/h)	21	−12.5	23 537	−5	55 741	−6	2 090 640	−6	118	555
10	Increase off-peak policy headways from 10 to 15 min	21	−12.5	21 043	−15	52 032	−13	1 952 380	−13	465	116
11	Minimize car miles rather than train hours subject to demand and policy constraints	22	−8	35 899	+45	49 491	−17	1 858 760	−17	25	116
12	Tests 6 and 10	21	−12.5	16 089	−35	48 267	−19	2 144 270	−4	641	358
13	Tests 6, 9, and 10	18	−25	14 849	−40	44 547	−25	1 980 590	−11	200	360

[a]Excludes spares. [b]Revenue service only. [c]Compared with baseline estimate.

Figure 1. Estimation of key transit supply requirements.



LOS, ridership estimates are prepared. Once the ridership estimates are available, the first step in supply-parameter estimation occurs: the development of operating plans. Operating plans are developed for each individual transit service and route included in the definition of a given alternative, and they specify the amount and temporal distribution of transit capacity to be provided. The operating plans should attempt to match supply with demand in ways that tend to minimize operating costs, subject to policy constraints (e.g., maximum headways) and technological constraints (e.g., minimum headways).

Operating plans must be checked to determine whether the maximum capacity that can be provided equals or exceeds the estimated demand. If not, the definition of the alternatives must be revised. For example, a rail alternative might require longer station platforms so that longer trains can be accommodated. In addition, the operating-plan LOS must be compared with the initial LOS used in the demand estimates. If there are substantial variances, revised demand estimates may be necessary. The need for such revisions is discussed below in further detail. Once an operating plan satisfies both of these checks, vehicle requirements and service measures (i.e., vehicle hours and vehicle miles) can be calculated. Next, the estimation of employee requirements by category completes the estimation of supply parameters.

A continuous activity in the process of supply-parameter estimation not shown in Figure 1 is the use of "reasonability" checks. These checks should be made of the supply-parameter estimates or underlying operating plans to determine their reasonability and consistency with respect to transit experience elsewhere that involves similar technology and operating conditions.

Supply-Demand Equilibrium

An imbalance between supply and demand in a transportation analysis can lead to unrealistic forecasts and erroneous conclusions. Consequently, there is a need in the alternatives analysis process to explicitly address supply-demand equilibrium. In the estimation of supply parameters, this need is reflected in the two key checks of the operating plan cited earlier.

The first check determines whether or not the operating plan provides sufficient capacity to meet or exceed demand. In essence, this check is asking the following: Given the physical, technological, and policy constraints of this alternative, is an operating plan feasible that provides adequate capacity to meet demand? If not, these constraints must be modified by revising the definition of the alternative. Of course, certain technological constraints cannot be modified, so that in an extreme case it may mean abandoning a particular technology.

Whereas the first check may lead to a direct change in supply, the second check may lead to a direct change in demand. Demand forecasts are necessary inputs for the development of operating plans and the estimation of key supply parameters. However, demand forecasts are predicated on certain supply-related parameters specified in the initial description of alternatives, particularly (a) headways and (b) line-haul speeds and travel times.

During the development of operating plans, changes may be made in both headways and speeds. Headways will change whenever demand headways (i.e., headways needed to provide adequate capacity to meet projected demand levels) govern rather than policy headways (i.e., maximum headways in a given time period specified as policy). Speed estimates may change as more accurate estimation procedures are used and as more detailed information is available about station volumes, vehicle performance characteristics, and alignment and station location.

Significant discrepancies (or inconsistencies) between headways and speeds used in demand estimation versus supply-parameter estimation imply disequilibrium between demand and supply. If, for example, operating-plan development results in lower headways and faster speeds than those used in demand estimation, greater ridership than initially predicted could be anticipated.

Often such differences in headways and speeds will not be so great that completely new travel demand forecasts will be required. Nevertheless, consistency checks are necessary, and feedback modifications of demand estimates may be warranted to ensure supply-demand equilibrium.

Iterative Nature of Process

The estimation of supply parameters is an exercise that is not restricted to planning. It continues beyond alternatives analysis into preliminary engineering, final engineering, and finally detailed operational planning. As the estimation of supply parameters proceeds from the early stages of alternatives analysis toward final design and detailed operational planning, the input assumptions must be examined more rigorously, the alternatives must be specified in greater detail, and the estimation procedures must be increasingly precise and accurate. The process itself, however, remains essentially the same.

Initially, supply-parameter estimation is directed at providing information in sufficient detail to distinguish between broadly defined alternatives; later, it provides information needed to assess the worthiness of a limited number of alternatives; finally, it is concerned with the design and optimal operation of a single alternative. Although there is considerable overlap, the discussion in this paper is aimed at requirements and procedures needed to conduct planning during the alternatives analysis process.

Phase 1 Versus Phase 2 Alternatives Analysis

As specified in the Urban Mass Transportation Administration (UMTA) policy on major urban mass transportation investments (3), the overall alternatives analysis process is divided into two sequential phases or stages. The first phase, "systems planning", is usually regional in scope and is aimed at establishing relative priorities among individual corridors and identifying a limited set of alternatives for each corridor that merits more detailed analysis. The second phase is a detailed alternatives analysis of a limited set of alternatives in a single corridor performed in conjunction with the preparation of an environmental impact statement.

A major concern in providing suggested guidance for the estimation of supply parameters is the distinction between the two phases of alternatives analysis. Unfortunately, this distinction cannot be drawn clearly and unequivocally because of the variability in site-specific circumstances and the range of alternatives considered. Clearly, studies in which the alternatives examined include additions to extensive rail systems will involve greater operational complexity than studies that consider a single rail line in an area where there are no existing rail services. Greater operational complexity generally requires more sophisticated procedures of supply-parameter estimation.

Although firm guidelines cannot be prescribed, it is possible to characterize, in an approximate sense, requirements and procedures for regional studies versus those of subsequent corridor-level studies. With respect to phase 1 systems planning studies, supply-parameter estimation should generally have the following characteristics:

1. It is geared for simplified operating-cost estimation.
2. Estimated supply parameters include vehicle miles, vehicle hours, and fleet size but not necessarily employees by category.
3. Operating plans focus on peak-period weekday services.
4. Relatively simple manual estimation procedures are used.
5. Only limited sensitivity analyses and interactions are performed.
6. Estimation procedures and reasonability checks may not be independent.

For subsequent phase 2 corridor-level studies, supply-parameter estimation should have the following characteristics:

1. It is geared for comprehensive operating-cost estimation procedures.
2. A complete set of supply parameters is estimated (such as that given at the beginning of this paper).
3. Operating plans specify weekday peak and off-peak service and possibly weekend service as well.
4. More complex estimation procedures are used, and there is likelihood of the use of computer-assisted procedures.
5. The iterative approach with extensive sensitivity analyses is used.
6. Reasonability checks are independent of estimation procedures.

Because supply-parameter requirements and appropriate procedures may vary by stage between different locations, it is important that federal and local sponsors make agreements in advance with respect to supply-parameter requirements, inputs, and estimation procedures. Although these agreements may require modification during the course of the study, they will serve as a blueprint for study conduct.

Operating Feasibility

As the analysis of transit alternatives proceeds, the definition of alternatives is continually refined and increasingly detailed. At the conclusion of the process, it is of obvious importance that the remaining alternatives be feasible from engineering and operational standpoints. Operational feasibility, as noted earlier, is of considerable relevance to the process for estimating supply parameters.

It should be emphasized that operational feasibility, as defined here, is concerned with whether or not a system or technology can actually perform as specified in a planning study. The fact that a system may be operationally feasible does not necessarily mean that it is operationally efficient. Relative operational efficiency must be determined by exploring different operating strategies through the use of the iterative planning approaches discussed earlier.

There are two major prerequisites for operational feasibility. The first is that relations between supply parameters, operating plans, vehicle performance specifications, demand levels, and various descriptors of alternatives be internally consistent. For example, there should be consistency (a) between average speed and vehicle performance, route characteristics, station (stop) spacing, station dwell time; (b) between vehicle passenger capacity and loading standards, vehicle dimensions; and (c) between vehicle requirements and route characteristics, demand levels, vehicle characteristics, minimum-maximum headways, vehicle reliability.

The second prerequisite is that the specification of various performance characteristics be within the capability of available technology and that this technology be specified in the capital cost estimates. Performance characteristics of particular concern to operational feasibility include vehicle performance and signal control (for rail technology).

SPECIFIC CONSIDERATIONS IN DEFINING ALTERNATIVES

A number of inputs and assumptions to the process of supply-parameter estimation are embodied in the definition of alternatives. Several of the most critical of these are discussed below.

Vehicle Capacities and Loading Standards

Some of the most significant assumptions in the determination of supply parameters involve vehicle capacity and associated loading standards. Despite the significance of these assumptions, there is considerable variability in the manner in which they are developed and in the resulting loading standards and vehicle capacities. Of particular concern is the tendency to use different loading standards for different transit modes in the same analysis, which tends to bias the analysis in favor of one mode.

There are really two basic issues to be addressed in determining vehicle capacity for use in supply-parameter estimation:

1. What are appropriate loading standards and seating plans for the service under analysis? Loading standard refers to how much space is made available per passenger in peak demand conditions. Seating plan refers to how this space is used for seated passengers and standees.
2. How can these standards and plans be used to determine vehicle capacities for different transit modes and vehicle types?

The first issue is largely a policy question that must take into consideration the nature of the transit service being analyzed and the cost implications of different loading standards. For services that have long average trip lengths, such as commuter rail operations, the ratio of total to seated passengers for design volumes is usually low, approaching 1.0 where a seat is planned for every passenger. Furthermore, a relatively large amount of space per seat may be used to increase passenger comfort.

As passenger trip lengths decrease and passengers are boarding and alighting more frequently, the total/seated passenger ratio typically increases and smaller seats are used. Table 2 (3-5) gives typical space requirements for seated and standing passengers. There is an obvious trade-off between total capacity and the amount of seating provided, since standing passengers consume less space than seated passengers. To increase available space for standees, seats can be either eliminated or reduced in size and different seating patterns (e.g., longitudinal instead of transverse seating) can be used. Reducing seating, of course, increases the frequency of conditions in which all seats are occupied and some passengers must stand.

In addressing this issue, policy decisions must be made with respect to (a) the percentage of passengers to be seated in the peak design period (ratio of total to seated passengers), (b) the amount of space to be allocated to seated passengers, and (c) the amount of space to be allocated to standing passengers. In using these decisions to determine the capacities of specific transit vehicles, it is likely that the seating configurations

Table 2. Space requirements for seated and standing passengers.

Category	Net Space per Passenger[a] (ft^2)
Seated passengers	
Typical commuter rail	4-6
Typical urban rail transit	3-5
Typical urban bus transit	3-4
Standing passengers	
In unconstrained condition	4-9
Minimum requirement to avoid contact	2.4-2.8
DuWag standard	2.7
NYCTA standard for maximum "practical" capacity	1.8
Moscow Metro minimum standard	1.3

Note: NYCTA = New York City Transit Authority.
[a]Excludes nonusable space. For seated passengers, the data include the space consumed by the seat plus leg space between seats. For standing passengers, the data are based on clear floor area per standee.

used elsewhere will be inconsistent in terms of space per seated passenger and the total/seated passenger ratio. Thus, for consistency, it is necessary to assume modified interior layouts for planning purposes.

One method of doing this is to use a constant loading standard expressed in gross square feet per passenger, where gross square feet is measured by exterior dimensions. Gross vehicle area is convenient to use since it is generally easier to determine than the amount of usable interior space. The Regional Plan Association (6) proposes a standard of 5.4 ft^2 of gross vehicle area per passenger.

One advantage of using a loading standard expressed in square feet per passenger is that the seating configuration does not need to be treated explicitly. By doing so, it is assumed that seating patterns could be developed for different vehicles under analysis that would have the same total/seated passenger ratio and would be equivalent in terms of space per seated passenger and space per standee.

It is important to recognize, on the other hand, that the loading standard expressed in square feet per passenger is not independent of space standards for seated and standing passengers and the total/seated passenger ratio. Thus, the loading standard should be selected based on the type of service being planned and its cost implications. This implies that an appropriate universal standard for all transit loading does not exist and that, in selecting a standard for a specific set of circumstances, consideration should be given to its implications for space for seated passengers and standees and the total/seated passenger ratio.

Another consideration in using loading standards based on gross area is that different transit vehicles may have different percentages of usable interior area compared with gross floor area. For rail transit cars, the Regional Plan Association found considerable similarity in this respect for rail cars. For transit buses and light rail vehicles, however, the percentage appears lower. Hence, using the same loading standard based on exterior dimensions may not be appropriate in comparisons between bus and rail.

In many instances, it may be simpler to compute vehicle capacities directly based on prototypical seating patterns and standee standards rather than to adjust loading standards based on gross floor area. The vehicle capacity calculations are straightforward once the following data are available:

Data Item	Source
Usable floor area	Data and specifications for production vehicles
Square feet per seat	Based on trip characteristics and industry experience (Table 2)
Square feet per standee (minimum)	Based on trip characteristics and industry experience (Table 2)
Total/seated ratio in peak conditions	Based on trip characteristics and policy decision regarding comfort

In computing capacity from these inputs, it must be remembered that the exact seating pattern implied may not be strictly possible. Door locations, passageway and wheelchair requirements, and other considerations are constraints on the interior layout of a transit vehicle. However, the loading plan developed should be feasible, at least in an approximate sense, and will ensure consistency in the estimation of vehicle capacities.

Service Hours and Service Days

Transit planning analyses are oriented toward peak-period weekday travel. Off-peak, weekend, and holiday services are not always given a great deal of consideration, though they can significantly affect annual supply parameters and operating cost estimates. Assumptions about such services are often treated implicitly in the factors used to expand supply parameters from peak-period to weekday totals and then from weekday to annual totals.

In the first-phase, regional-level alternatives analysis studies, the use of approximate expansion factors, without a detailed consideration of service levels in off-peak and weekend time periods, can be appropriate provided the factors are reasonable in light of local and national experience. In subsequent corridor-level studies, however, supply parameters should be developed based on explicit assumptions regarding off-peak, weekend, and holiday service levels.

In developing weekday supply-parameter estimates during corridor studies, service levels can be specified in three to five time periods during which service levels are assumed to be reasonably constant: peak (morning and evening), base, night, and "owl". It must be recognized that dividing a weekday into a limited number of constant service time periods is a simplification, albeit a necessary one. Transitions between time periods, special "tripper" runs, and other scheduling considerations typically produce hourly variations so that, in larger transit systems, no two hours are exactly the same.

To develop annualization factors--factors that expand weekday supply parameters to annual supply-parameter estimates--explicit assumptions regarding weekend and holiday service are necessary in corridor-level alternatives analysis studies. The sensitivity of annualization factors to weekend and holiday service assumptions is given in Table 3.

Another important consideration in developing annualization factors is seasonality. Bus transit systems often provide special revenue school runs when school is in session. Fares are charged and anyone may use the service, but it is oriented toward schoolchildren. Such service may represent a sizable proportion of background bus services and should be taken into account in developing annualization factors. In addition to school-related service, some transit systems have seasonal service variations related to recreational travel and climatic conditions, though they tend to be minor.

It should be noted that annualization factors are not necessarily the same for different supply parameters. For instance, in the case of rail lines, trains are likely to be shorter on weekends so that the reduction in vehicle miles, compared with weekday service, is greater than the reduction in train hours. Strictly speaking, such differences imply that different annualization factors should be used for vehicle miles and train hours. For regional-level studies, however, the use of a constant annualization factor for supply-parameter estimation is a reasonable approximation. In corridor-level studies, annualization factors should be developed with great care and, where appropriate, different annualization factors should be used for different supply parameters.

Table 3. Annualization factors: sensitivity to weekend and holiday service.

Service (%)				Annualization Factor
Weekday	Saturday	Sunday	Holiday	
100	-	-	-	251
100	50	-	-	277
100	70	-	-	287
100	70	40	40	311
100	50	50	50	308

Note: Assumes nine holidays per year and no seasonal variation in transit services.

Background Bus Networks

In analyzing capital-intensive transit facilities, facility alternatives are superimposed over existing or proposed bus systems in the corridor. The extent and cost-effectiveness of the background bus system are important because the evaluation of alternatives will consider the ridership, revenues, and costs of all transit services in the corridor.

As a minimum, the background bus system must be modified to interface with the capital-intensive line-haul system under consideration and reduce or eliminate service duplication. In addition, the background bus system may be modified to provide additional feeder-distribution service for the line-haul service and also may be expanded to include new services that are warranted by anticipated growth and are unrelated to the line-haul system. In the latter case, the background bus system is usually based on an improved "all-bus" alternative for the corridor.

In developing background bus systems for alternatives analysis, a number of questions must be addressed. Some of the most critical questions include the following:

1. Should all capital-intensive facility alternatives be superimposed over the same background bus network with only interface changes and route truncations and eliminations to reduce service duplication?
2. Should the background bus network be based on an "existing" or improved bus network?
3. Should there be an attempt to "optimize" the background bus network for individual capital-intensive facility alternatives?
4. Can individual bus lines be aggregated to simplify the analysis?
5. How should the treatment of background bus systems vary between regional-level and corridor-level studies?

In completed alternatives analysis studies, it appears most often that capital-intensive corridor facility alternatives have been superimposed over essentially the same background network and that the basis for this network is usually an "improved" all-bus alternative. Although the background network was often modified to provide feeder and distribution services, formalized attempts to determine the "optimal" bus network were not made. Bus networks were analyzed at the level of detail usually required for an Urban Transportation Planning System transit network (i.e., all background bus transit services were generally coded into the network). Note that completed studies have mostly been corridor-level rather than regional-level studies.

In making recommendations for the treatment of background bus networks in future alternatives analysis studies, no radical departure from past practice appears warranted, but some guidelines for consistency are needed. Recommendations in this regard are summarized below:

1. Essentially the same background bus network should be used for all capital-intensive facility or service alternatives.

2. The basis for this network should be an improved bus network that reflects service increases warranted by projected growth and applicable transportation system management improvements.

3. The background network must be modified for each line-haul facility or service alternative to provide appropriate interfaces and eliminate service duplications. Service duplications should only be eliminated to the extent that they could actually be eliminated. Experience with the Bay Area Rapid Transit system and the Washington, D.C., Metro system indicates that there may be substantial community opposition to the elimination of bus routes that, although they duplicate rail service, may offer a better level of service than rail or may provide local service that rail cannot provide. Bus routes that duplicate a proposed line-haul transit facility and that would offer service clearly inferior to that provided on the other facility can usually be eliminated or truncated without question.

4. No formalized attempt should be made in alternatives analysis to develop an optimal background bus network for capital-intensive facility alternatives. However, obvious modifications to the bus network should be made to provide adequate feeder and distribution services. At the conclusion of the analysis, supply-demand checks should be made to determine whether the services in the background network, especially feeder service, are in equilibrium. Furthermore, reasonability checks of riders per bus mile and riders per bus hour should be made to determine the relative productivity of the background bus network for different capital-intensive line-haul alternatives. These checks may indicate the need for refining the specification of the background network for a particular line-haul alternative. Usually, such refinements can be made manually without changing computer networks and repeating the travel demand forecasts.

5. Aggregation, or the schematic treatment of individual background bus routes, is appropriate for regional-level studies. In corridor-level studies, supply-parameter estimation and demand estimation will require more detail, and therefore the specifications for background bus networks should be at the level of individual routes or lines within the corridor under study.

CONCLUSIONS

Through an example, a discussion of general considerations, and detailed discussions of selected topics, this paper has attempted to reveal the complexity and significance of the estimation of transit supply requirements in planning studies. Although the paper has been written in the context of federally required alternatives analysis studies, the principles and concerns raised are applicable to transit planning generally, particularly any planning efforts in which fixed-guideway transit modes are considered and alternative transit modes evaluated.

The paper is not comprehensive and has focused its most detailed discussions on selected inputs to the supply-parameter estimation process that require special attention. Many other important inputs to the process were not covered, and the entire subject of how these inputs are used to calculate supply-parameter estimates was not addressed at all. It is hoped that this paper will stimulate interest and further discussion of supply-parameter estimation among those planners actively involved in transit alternatives analysis studies.

ACKNOWLEDGMENT

This paper reports the results of research sponsored by the Transportation Systems Center and UMTA of the U.S. Department of Transportation. The views and recommendations presented, however, are mine and do not necessarily reflect the position of the research sponsors.

REFERENCES

1. Estimation of Key Transit Supply Requirements. Alan M. Voorhees and Associates, McLean, VA, draft, spring 1980.
2. Urban Mass Transportation Administration. Major Urban Mass Transportation Investments: Statement of Policy. Federal Register, Vol. 41, No. 185, Sept. 22, 1976, pp. 41512-41514.
3. B. Pushkarev and J.M. Zupan. Urban Space for Pedestrians. M.I.T. Press, Cambridge, MA, 1975.
4. H.D. Quinby. Mass Transportation Characteristics. In Transportation and Traffic Engineering Handbook, Institute of Traffic Engineers, Arlington, VA, 1976, pp. 207-257.
5. E.S. Diamant and others. Light Rail Transit: State of the Art Review. U.S. Department of Transportation, 1976. NTIS: PB 256 821.
6. Where Rail Works: An Exploration of Travel Volume Criteria for Fixed Guideway Transit. Regional Plan Assn., New York, draft, 1978.

Publication of this paper sponsored by Committee on Transportation Systems Design.

Development of Regional Multimodal Transportation Performance Measures for the Twin Cities

WILLIAM R. LOUDON, WENDY P. STERN, AND JOHN F. HOFFMEISTER

Results of a study performed to develop measures for assessing the effectiveness of the transportation policies of the Metropolitan Council of the Minneapolis-St. Paul area are presented. The purpose of the study was to develop a set of performance measures for assessing the degree to which the Metropolitan Council's regional transportation policies were being adhered to and the extent to which the policies have been effective in attaining the basic objectives of the region. Two important innovations in the study were the emphasis on planning versus management performance measures and the development of three sets of measures—one to provide an overview of transportation in the region, one to assess objective attainment, and the other to determine policy