Methods for Service Design

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This paper explores current practice in the design of bus services. It focuses on methods used to identify problems in the existing system and to design service changes. Current practice is handicapped by the lack of reliable data of a type desirable for good planning, and problem-identification activities consist mainly of flagging routes that rank low in terms of cost-effectiveness indices. As a result, only a small set of potential improvement actions are usually considered, and the (usually implicit) objectives in providing transit service are not effectively included in the process. The paper then recommends changes to the existing process that would encourage planners to look for opportunities that may exist on routes that are not flagged as substandard. Modifications are also proposed that recognize the multiple objectives that transit operators should be dealing with.

This paper is intended to provoke discussion on the effectiveness of current approaches to service design in the transit industry. Although service design has always been an important, perhaps even central, element in short-range transit planning, (SRTP) changes in the environment within which transit operates is placing increased stress on this function. During the past decade service planning took place, increasing resources were made available for transit, and the focus was on issues of service expansion. Now tighter financial constraints are forcing operators to look for ways of getting more out of existing resources, and often the question is where and how to reduce service. Approaches to service planning appropriate in the recent past may be less satisfactory in the future given this shifting emphasis.

SRTP: SCOPE AND BASIC ACTIVITIES

SRTP is the process of monitoring the operations of the transit system and planning modifications that can be implemented during the next schedule change.

An important implication of this definition is the short time frame of SRTP; in particular, some changes to the transit system are not available in SRTP. Examples of these actions include the acquisition of new vehicles, changes in the general configuration of the network (e.g., grid versus radial), changes in the fare structure, planning of major capital facilities, and the introduction of new transportation modes. Decisions related to these options are usually the domain of longer-range planning and programming that should, of course, be coordinated with SRTP.

The remaining system modifications, those feasible during SRTP, can be grouped at various levels: The system coverage level, the route structure level, the frequency level, and the control level (1). A distinction can be made at each level between actions that tend to increase cost and ridership and those that tend to decrease cost and ridership. Depending on the financial (and other) constraints that face the property, actions taken may be predominantly of one type or the other or may be a mixture, in which case the system is being fine tuned to better meet the objectives of the agency. Of course, system fine tuning may also include actions aimed at more efficient production of the same level of transit service.

At the highest level, feasible actions include implementation of a new route, extension of an existing route, replacement of a small set of routes with a new set, discontinuance of service on a route, shortening of a route, and the making of minor modifications in route alignment. Another type of action at this level is substitution of a privately provided service for the existing publicly operated fixed route. This new service might be paratransit or fixed route, the aim being to reduce cost and provide a more suitable service. Actions at this level are the most disruptive for the public and so merit the most intense scrutiny. Consequently, many of these actions are among the most time-consuming to plan and implement within the short-range planning process.

Actions at the route-structure level are the splitting of a route into two nonoverlapping segments, the splitting of a route into zones or express and local segments, the linking of two existing routes to form one new one, and the introduction of deadheading of some buses of a route. Although these actions are generally less disruptive than changes in system coverage, they do require some reeducation of the public and careful planning.

At the frequency level more or less service can be provided on a given route at a specific time of day. Finally, at the control level, the following actions, usually aimed at maintaining closer adherence to the schedule, are considered: installation or removal of a control point on a route at which slack is built into the schedule, a change in the running time allowed for a route segment, and modification of the layover time (a special case of the first strategy).

Notice that this set of system changes contains general modifications that can be applied to any part of the network during any time period. Because of their generality, we refer to these changes as generic actions. An alternative is defined as the application of a generic action to a part of the transit system. For example, an alternative may consist of applying the generic action frequency change (for example, service reduced from five to four buses/h) to a specific route during the morning peak.

Based on the definitions given above, a more operational definition of SRTP can be developed. It can be viewed as the process of determining where on the existing system and during which time period generic actions should be taken to develop the most promising alternatives for implementation during the next schedule change.

The list below summarizes the generic actions in SRTP. Although the number of generic actions is small, SRTP is complex because the number of elements of the transit system to which each generic action can be applied is large, which results in an even larger set of feasible alternatives:

1. Area coverage level--new route, route extension, a small set of routes replaced by a new set, route abandonment, shortening a route, route realignment, and change of service type or operator;
2. Route structure level--route splitting, zonal service, express or local service, linking of two routes, and deadheading;
3. Frequency level--changes in route frequency; and
4. Control level--installing or removing control points, changes in layover time or positioning time; and modifying running times.

This requires that SRTP, like most complex planning problems, be structured around the following set of basic, sequential activities:

1. Problem identification,
2. Design of alternatives,
3. Analysis of each alternative, and
4. Recommendation of the most promising alternative.

Problem identification involves the gathering and review of data on individual services to determine whether or not a problem exists. The idea of problem identification clearly implies that the objectives in providing the service are not being well met and that some change in the service may be warranted. Problem identification is an ongoing process that must be supported by some type of data collection and analysis.

Once a problem has been found, one or more generic actions could be taken to alleviate it. The design of alternative actions may be quite straightforward or difficult. For example, a route that exhibits extreme crowding would obviously be considered for increased service frequency whereas a route that has very unreliable service might be a candidate for several different generic actions.

Each alternative is subject to some type of analysis to predict the impacts of adopting it. This analysis process is often largely judgmental, but it may include one or more models to predict impacts. The planner will be concerned about impacts such as

1. Changes in operating costs based on driver and vehicle requirements or
2. Changes in ridership and revenue.

More generally, also considered would be the extent to which the initial problem would be corrected and the degree to which underlying transit objectives would be furthered.

Once the impacts associated with each alternative are predicted, the most suitable alternative can be recommended based on review of the possibilities by different departments within the organization and, in many cases, with external groups as well. The extent of internal and external discussion and negotiation will, of course, depend on the generic action being considered. Typically, a lengthier process is involved in determination of the best service-reduction-type action in which the public is adversely affected than if an expansion-type action is being taken.

CURRENT PRACTICE

General statements about current practice in the transit industry are dangerous because of the diversity of methods used among operators of different size and in different parts of the country. Furthermore, in the amount of space available in this paper, it is impossible to report on all the different approaches to planning now being used for each of the basic activities identified in the preceding section. Consequently, here we will focus on the first two activities--problem identification and design of alternatives. Despite the dangers, this discussion will be couched in general terms; recognize that there are exceptions to most of the points made. The discussion of current practice that follows is based on our personal experience and information available in the transit literature (1-5).

One of the most important influences on SRTP is the type and quality of information available to the planner. Currently, the variation is great among properties in the data available in terms of the type, level of detail, frequency, and amount of data collected, and perceived quality. Recently many properties have reevaluated their data-collection programs in light of Section 15 reporting requirements of the Urban Mass Transportation Act of 1964, as amended, and the need to make tough choices on where service cuts should be made. Even so, there is still room for the improvement of most data-collection programs by more formal consideration of accuracy and sampling issues (6). Many planners, particularly those in the larger transit authorities, think that they do not obtain the type and quality of data on existing services needed to make sound planning decisions. In some cases this problem is exacerbated by tensions or poor communication within the property among those who collect the data, the planners, and the schedulers. These organizational difficulties are not as common in smaller agencies that can also often make effective use of information informally received from drivers and starters.

Typically, raw data must be summarized or processed before it is in a form useful for the planner. Here again, industry practice varies widely: Many properties rely on completely manual tabulation and file storage, and others have moved aggressively toward computerization. If data are handled manually, it can be quite difficult, particularly when urgent actions are required, as in a budget crisis, to bring disparate types of data gathered at different times to bear effectively on an analysis of a particular route or set of routes.

Whatever information is available from data-collection activities and other input, such as passenger suggestions and complaints, is used to evaluate current services and to identify problems that require attention. This type of analysis typically looks for unacceptable performance as defined in terms of measures and standards that may have been formally adopted by the property or just be based on the experience of the planner. Services may also be flagged for further study if they appear to have changed significantly over time, even if they are not substandard. This type of analysis is often hampered by lack of a composite picture of a route (a route profile) from earlier data collection and analysis cycles.

Central, then, to the problem-identification phase of current SRTP is the use of service measures and, to a lesser extent, service standards. Service measures are statistical summaries of route data such as passengers per bus hour, revenue per cost, and percentage of buses on time, whereas service standards establish a critical level for a particular service measure, such as 25 passengers/bus hour as the minimum acceptable level of productivity for a route (7).

Service measures are used by virtually all properties but, although many different measures have been proposed, rarely does a specific agency use more than three in route planning. Principal reasons for this are that planners focus on only a few problems, such as overcrowding or underuse, that can be represented by a few measures, and the quality and amount of data and limited planning resources preclude effective use of more measures. The vast majority of service measures used are ridership oriented, such as passengers per bus hour, passengers per bus mile, and peak load factor. Other service measures that are commonly used are subsidy per passenger, revenue per cost, and on-time performance. These measures accurately reflect the primary concerns of most properties with ridership and cost-effectiveness and the dominant role that schedules play in modifying the services provided.

Service standards are more often used as guidelines to indicate when a route may be in need of study than to dictate that a specific change should be made. Ridership and revenue-oriented standards are generally used to flag poorly performing routes that are well below average performance for the system as a whole. Beyond this screening role, these measures are not used effectively in planning route changes. On the other hand, measures that are directly related to possible schedule changes such as peak load factor and schedule adherence are often used directly to design changes. As expected, the actual standards used for specific measures vary greatly among properties, depending on their size and financial situation.

One of the important benefits of establishing service policies in the form of measures and standards should have been to encourage operators to think hard about the objectives behind the provision of transit service in that metropolitan area. This process was badly needed after the shift of the industry from the private to the public sector removed the profit-maximization objective. Unfortunately, it is now common in the transit industry to find goals and objectives, where they are stated at all, couched in general and vague terms. Little guidance is given from above about relative priorities and the resolution of conflicting objectives, so the planner is left very much alone in defining useful measures to identify problems and later in the evaluation of alternatives. Where standards are used, it is not clear that the levels have been chosen soundly or what the impacts of changing them would be on achieving agency objectives. Indeed, the ease with which some agencies have made significant changes in these standards suggests that the standards may be arbitrary and serve to simplify the planning problem without a sound basis.

Once a problem has been identified through the collection and analysis of data, specific alternatives must be designed to deal with it. If the problem is minor, for example, heavy loads on a route or poor schedule adherence, the solution will often be quite straightforward, such as adjusting running or recovery times and adding bus trips. These scheduling changes can generally be implemented without extensive analysis in the next driver pick provided that budgetary or vehicle fleet constraints do not prevent the obvious solution and that the required schedule changes can be accomplished in time.

For more substantial problems a planner will often be given responsibility for development of alternative actions and their analysis and evaluation. Frequently input will be obtained from drivers, supervisors, and the community, and additional data may be collected to clarify the problem and on which to base the design of solutions. In some cases design standards are used such as policy headways or route-accessibility guidelines to suggest appropriate types of changes and to disqualify other proposals. Often a planner will have a portfolio of route changes that he or she would like to make if an opportunity presents itself; some changes will originate internally and others will come from riders or the community in general. Political pressure is often a factor in the selection of routes for service reductions and most planners will think about political reactions before recommending specific change. This is a major factor in the retention of some extremely poor routes for which no useful strategies can be developed for improving performance. It is fair to say that the process of designing useful changes for routes that have been flagged as substandard in terms of cost-effectiveness is not very productive. Thus, schedule changes represent the clear majority of service changes implemented during any planning cycle.

In summarizing current short-range planning practice the following critical points should be noted:

1. The type and reliability of data available to the planner severely limit his or her ability to identify problems with the system and to design effective responses to problems that have been identified.
2. Even if reliable data were available, an important problem that needs to be addressed is how to summarize and use these data to help the planner in problem identification and design of alternatives.
3. Although service standards are effective in identifying routes that can be improved with scheduling changes, service standards that flag poor routes in terms of cost-effectiveness are not so effective in identifying routes that can be changed to better meet the multiple objectives of the agency.
4. The process of designing specific alternatives to solve problems at the route level is ad hoc and is probably not effective in identifying changes such as express, zonal, or deadheading services that might improve performance.
5. In an environment of decreasing planning resources and increasing pressure to get the most out of transit subsidies, the basic objectives in providing transit service at all must be included more directly in the design of changes in individual services.

PROPOSED SRTP PROCESS

The proposed short-range planning process is a modification of the current process that tries to address the weaknesses that were identified in the previous section. In addition, it recognizes, unlike many previous methods for system design, that SRTP occurs in a complex institution. [For a review of some of these methods, see Furth (8) and Furth and Wilson (9)]. The following characteristics of transit operating agencies are incorporated, either as constraints or guidelines, in the proposed method.

1. Multiple goals--The SRTP process must recognize that properties have multiple goals such as providing mobility for those without automobiles, reducing traffic congestion, and reducing energy consumption. These goals are associated with specific routes (that serve specific markets) and times of day (e.g., congestion occurs principally during peak periods). Thus, analysis and design must be based on data at the route and time period levels.
2. Coordination with related activities in the agency--Short-range planning is only one activity within a property and its effectiveness depends on the interfaces with other elements of the organization. For example, after approval, actions recommended by planners must be implemented by the scheduling group. Only by considering the interdependencies between SRTP and other activities can it be ensured that actions recommended by planning will be acceptable to the total organization.
3. Constraints in planning resources--Planning resources available for SRTP (principally time and personnel) are tightly constrained; thus, it is important to focus attention on services that have high potential for positive payoff. Since detailed analysis of all possible alternatives and services is impossible, a screening procedure is essential. This also implies that large-scale or radical changes that require extensive analysis and run-cutting cannot usually be undertaken.
4. Changes in the agency's environment--SRTP has to be able to respond effectively to changes in the operating situation of the agency, such as sudden changes in budget.

5. Limitations of technical analysis--Since the state of the art in transit technical analysis is imperfect, quantitative methods should be used to supplement the planner's judgment and experience, not to replace it.

The presentation of the proposed SRTP process will be structured around the basic steps of SRTP that are being emphasized in this paper: problem identification and design of alternatives. In transit, the problem-identification step usually also includes a preliminary design of alternatives because a set of solutions (or generic actions) is often directly associated with each problem. For each of these steps, modifications to current practice will be proposed, both in terms of the processes followed and the required data and analytical support.

Regarding the data and analytical support for the problem-identification and design-alternative steps, note that, although the general requirement of both steps is quite similar, the levels of detail are very different. In problem identification, a large number of routes have to be screened; thus, because of the time constraints, detailed route analysis is inappropriate. For this step, simple aggregate performance measures are used. Design of alternatives, however, requires more detailed information and analyses, many times by route segment and time period. These analyses can be undertaken for the relatively small number of routes that have previously been identified as good candidates for changes.

Problem Identification

Problem identification as implemented in current practice has two basic limitations. First, the term problem is often used as a synonym for substandard performance. This narrow definition usually excludes routes that, although currently performing satisfactorily, could be improved significantly. The second limitation is that the multiple objectives of the transit agency are usually not incorporated in the problem-identification step. For example, routes that have a low revenue-to-cost ratio are usually considered substandard; however, this low ratio may be caused by a large number of elderly passengers, which is usually viewed as an asset.

Defining Problems in SRTP

For dealing with the first limitation, a better definition of problem is required. For developing this definition, recall the concept of generic action that was introduced earlier in this paper. These actions are the control variables available to the agency to modify its system in order to improve its performance. With this in mind, we define a problem route as one whose performance could be significantly improved with the application of one of the generic actions. This definition encompasses both types of problem routes of interest, those that are substandard, for example in terms of schedule adherence or productivity, and those whose efficiency in providing a given service could be improved.

We recognize that both types of problems are important for problem identification; however, because they are very different, different methods are required. Both methods, however, are based on relations between generic actions and types of problems.

The first method, referred to as the problem-centered approach, is similar to current practice. The major difference is the recognition that the generic actions that are applicable for dealing with a specific problem is a small subset of all the possible actions. This implies that, to narrow down the set of all possible changes to a small subset (which is the role of problem identification), we just need a set of performance measures that will indicate the existence of a problem in any given route.

Table 1 presents the starting point for the (traditional) problem-centered approach. In this table we present the most important performance indicators required to identify each type of problem and its possible solutions. Note, however, that in this table we are not directly incorporating the multiple objectives of transit operators. This issue and methods to deal with it are discussed later.

The second approach to problem identification is most appropriate for improving parts of the system in which heavy pressure for change does not currently exist; i.e., for routes that have no obvious problems. The key to this approach is realizing that the potential of any generic action for improving the performance of a route is dependent on the existence of a set of conditions on that route. The problem then becomes one of identifying the set of conditions that will indicate the potential for each generic action and finding measures for these conditions. Since this type of problem-identification approach is structured around the generic actions, we refer to it as generic-action centered.

Principal advantages of this generic-action-centered search are twofold. First, actions that are not usually appropriate for problem routes are included directly in the set of potential service improvements. For example, problem routes are usually characterized by low ridership and policy headways, and actions such as express or zonal routing or partial deadheading will never be of value for these routes, and hence may never be considered by the planner. Second, some routes that are not problems will be the subject of planners attention, which may result in implementation of unusual actions such as zoning or deadheading that might either free resources to tackle problem routes or improve overall service quality.

Table 2 presents the starting point for the generic-action-centered approach to problem identification. It contains each generic action and the set of conditions that indicate its potential.

Notice that, for measuring these conditions, several types of indicators may be required. For example, schedule adherence can be characterized by a numerical indicator such as percentage of trips that are late. For identifying a point on a route that has low ridership, which is required for several generic actions, a graphical load profile, similar to the one shown in Figure 1, may be most appropriate (10). For measuring the potential for a route extension, a map in which areas of new development and possible traffic generators are marked may be useful. Locations of possible bus turnaround points, which are important for route extensions and splitting, may also be plotted on a map. Verbal indicators may consist of comments from planners, supervisors, and drivers that could later be verified with data.

Of course, the choice of which measures or indicators to use, for both the problem- and generic-centered approaches, will depend on the cost, accuracy, and reliability of each type of information as well as on the data currently available to the operator. For example, suggestions or comments from drivers will cost very little, but the reliability of this method will depend on the availability of mechanisms and incentives to transmit the information accurately. Performance measures can be used only if there is an ongoing data-collection effort, which will probably provide the most reliable information, but in a more costly manner.

Multiple Objectives and Search

The other limitation of the current problem-identification process is that it does not recognize the multiple, and often conflicting, objectives of the transit agency. When dealing with multiple objectives, it is not possible to find a single measure that indicates goal attainment; usually different measures will be required for each goal. For example, a measure such as number of elderly riders could be used to evaluate the performance of a route with respect to the goal of providing service to the elderly. Another measure for this goal could be the percentage of elderly within 0.25 mile of a route. For the goal of cost efficiency of service, the traditional revenue-to-cost ratio can be used.

Since some goals are conflicting, attainment of an acceptable level in one of them sometimes results in difficulties in meeting another. For example, a route that serves many elderly will often have a low revenue-to-cost ratio because of low fares for the elderly. To deal with this problem, we propose ranking all the routes in terms of the performance measures selected for each goal. It is important to do this ranking by corridor (or area) and time period because, in this way, only similar services will be evaluated against each other and spatial and temporal equity will also be taken into account. These rankings can then be used as a screening mechanism; for example, for the goal of cost efficiency, the routes in the lowest 10 percent revenue-to-cost ratios that are not in the upper 20-30 percent in the rankings for other goals could be screened for further analysis.

To demonstrate the feasibility of this approach, a computer program to summarize the required information has been developed. The output of this program is presented in Figure 2. In this particular case, the variables used are passengers per trip for different fare categories, total passengers per trips, and revenue per trip. Of course, other measures could also have been used.

The report shows the ranking and values of the measures for each route in the system. Two summary variables that indicate the number of measures for which a route belongs in the upper and lower 15 percent are also included and routes are further cate-

Table 1. Problems and corresponding actions.

Problem	Indicator	Possible Action
Schedule adherence	Percent of trips late	Holding strategy, increase run time or layover, modify route
Unacceptable crowding	Load	Increase frequency
Poor productivity	Revenue/cost	Decrease frequency
	Load	Split route
	Passengers per vehicle hour	Short turn strategies; local, express, zonal strategies; partial deadheading
Poor vehicle use	Revenue/cost	Eliminate route segments
	Passengers per vehicle hour	Eliminate trips, extend route, modify schedule

Table 2. Generic actions and appropriate route conditions.

Generic Action	Route Condition
Holding strategy	Schedule adherence problem, long route, point on route with low through ridership
Increase running	Schedule adherence problem
Layover time	Low loads
Increase frequency	Unacceptable crowding, moderate rather than high ridership, even load profile
Decrease frequency	Low productivity and loads, headways below policy levels
Split route	Low productivity, uneven load profile, long route
Short turns	Tapering load profile, long route, high ridership
Express or zonal	High ridership, tapering load profile, long route, large time differentials local or express zone
Partial deadheading	Large imbalance in flows, large time differential in service and high frequencies
Eliminate route segment	Low ridership generation on segment, vehicle savings possible from elimination, higher frequency possible from elimination
Eliminate trips	Low ridership on trips, high cost savings from elimination

Figure 1. Plot of cumulative boardings and alightings for trip in a given direction.

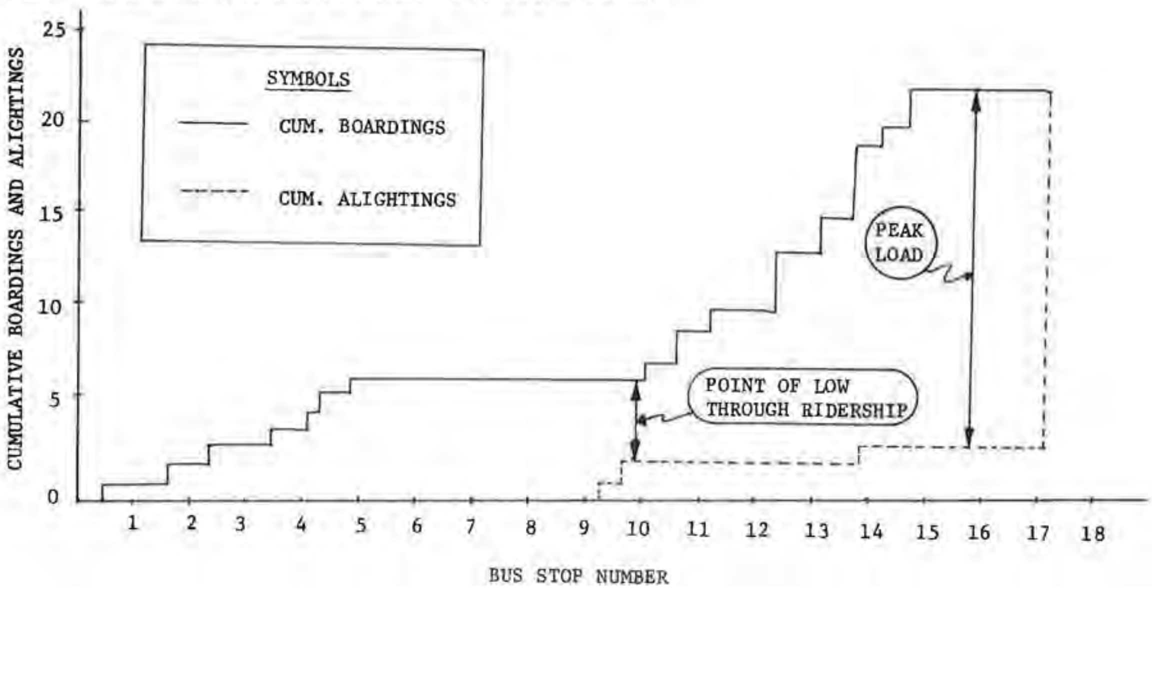


Figure 2. Multiple-objective ranking table for problem identification.

ROUTE	DAILY SCHEDULED TRIPS	THE VARIABLES BELOW ARE, FOR EACH CATEGORY, THE AVERAGE PER TRIP AND THE RANK																NO. OF CATEGORIES IN TOP 15%	NO. OF CATEGORIES IN BOTTOM 15%
		REVENUE		TOTAL PASSENGERS		REGULAR		TRANSFER		STUDENT		ELDERLY		HANDICAP		CHILDREN			
		AVG	RANK	AVG	RANK	AVG	RANK	AVG	RANK	AVG	RANK	AVG	RANK	AVG	RANK	AVG	RANK		
NOTE: THE ROUTES THAT FOLLOW ARE IN THE TOP 15% FOR AT LEAST ONE CATEGORY WITHOUT BEING IN THE BOTTOM 15% OF ANY CATEGORY																			
1	104	$15.26	2	52.72	1	26.36	1	13.18	1	2.11	2	5.27	2	0.53	3	5.27	1	7	0
2	54	$15.53	1	49.54	2	26.25	2	11.89	2	0.99	6	7.43	1	0.99	1	1.98	3	6	0
3	78	$6.95	6	23.97	4	10.55	7	5.99	3	2.40	1	3.59	7	0.24	10	1.20	5	1	0
4	30	$6.84	7	19.83	7	9.72	9	1.98	8	1.98	3	4.96	3	0.59	2	0.59	8	1	0
13	26	$7.27	5	22.60	6	11.52	6	3.39	6	1.81	4	3.39	8	0.45	5	2.03	2	1	0
NOTE: THE ROUTES THAT FOLLOW ARE NEITHER IN THE TOP OR BOTTOM 15% IN ANY CATEGORY																			
5	68	$8.91	3	24.00	3	15.60	3	3.60	5	0.48	10	3.60	6	0.24	9	0.48	10	0	0
8	66	$7.75	4	23.86	5	12.17	5	4.77	4	1.19	5	4.77	4	0.48	4	0.48	11	0	0
9	24	$6.79	8	16.82	10	12.45	4	1.68	10	0.34	12	1.68	10	0.17	12	0.50	9	0	0
10	24	$5.98	9	16.90	9	9.47	10	1.69	9	0.34	11	4.23	5	0.34	7	0.85	6	0	0
12	42	$5.93	10	17.17	8	10.30	8	2.58	7	0.86	7	1.72	9	0.34	6	1.37	4	0	0
NOTE: THE ROUTES THAT FOLLOW ARE IN THE BOTTOM 15% FOR AT LEAST ONE CATEGORY WITHOUT BEING IN THE TOP 15% OF ANY CATEGORY																			
6	46	$4.76	11	12.18	11	8.28	11	1.22	12	0.85	8	1.22	11	0.24	8	0.37	13	0	1

gorized by these variables. The group on top consists of those that perform very well with respect to some measures and are at least average in the others. The last group contains routes that are the worst performers in some categories and are not good performers in any single category. These are candidates for remedial action. The analysis presented in Figure 2 can be applied to different types of data. In this particular case, monthly revenue by route was used, together with judgmental estimates of the percentages, by route, of each fare category. These data are usually available to most operators. If fare classification counts were available, these could also have been used and would have provided more accurate input to the program.

It is interesting to look at routes 4 and 13 in the table. By using traditional ranking schemes based on revenue/cost and other economic performance measures, these routes would probably have been flagged for remedial action. However, as our analysis points out, these are excellent performers with respect to other objectives. This, of course, should be considered when recommending any service changes.

Design of Alternatives

The output of the problem-identification step is a small subset of routes that have the potential for improvement by the application of one or more generic actions. The purpose of the design-of-alternatives step is to develop detailed alternative changes for these routes that can then be evaluated for possible implementation.

The analyses required for this design stage are more detailed because during it specific decisions about where and when to implement the generic actions have to be made. This more detailed analysis is possible because the number of routes now being considered is much smaller. As an example, assume that a schedule-adherence problem has been identified on a route. To develop a specific alternative solution to this problem, information on route segment level actual running times may be required. For more detailed analysis of a potential service cut, segment-level ridership data by passenger type may be needed.

Again, this information may be collected and summarized in different ways. Estimates of route segment ridership may be obtained from bus drivers. Alternatively, data collected through riding counts can be used.

To aid this design step, several computer programs to analyze and represent riding count data have been developed. One example is the graph presented in Figure 1, which shows cumulative boardings and alightings by stop. This will provide the detailed segment-level information required for design. It gives totals and percentages of route ridership by segment. Figures 3 and 4 provide time-period information about elderly and transfer passengers, respectively, that is required to assess the possible impacts of the changes on these groups.

A situation that would require a different type of process at this detailed design step is the development of alternatives to better meet the overall objectives of the agency. Unlike other situations, a set of predefined solutions (like route splitting) does not exist for this case. What is proposed is for the agency to develop in advance sets of alternatives for each of its goals. In this way, if the situation requires implementation of improvements aimed at the attainment of a specific goal, the appropriate set of alternatives can be used as a starting point. By having this preliminary design ready, the operator will be in a better position to implement these changes quickly when circumstances so dictate.

Interface of SRTP with Other Activities

SRTP is only one of the activities for which the transit agency is responsible. The other required activities of the transit operator include the following (11,12):

1. Scheduling--runcutting, driver assignment;
2. Operations--driver supervision;
3. Marketing and community relations--communication between the agency and the public; and
4. Administration.

All these different activities are interrelated with SRTP, perhaps the most important relations being among operations, scheduling, and planning. These are inextricably linked to each other in the planning and implementation of transit service. For example, it is very important that operational constraints be introduced into SRTP at an early stage to ensure that the proposed changes are acceptable in a practical sense as well as in a theoretical one. The interrelation between runcutting and cost estimation also requires close coordination between SRTP and scheduling. Only in this way can alterna-

Figure 3. Report of transfer passengers for route 2.

ALL THE STATISTICS PRESENTED BELOW ARE FOR TRANSFER PASSENGERS

									BETWEEN DAY		WITHIN PERIOD		
TIME PERIOD	DIRECTION	DAYS SAMPLED	DAILY SCHEDULED TRIPS	EXPANDED TOTAL	PERCENT OF TOTAL	AVERAGE PER TRIP	90% CL LOWER BOUND	90% CL UPPER BOUND	VARIANCE	COEFF. OF VARIATION	VARIANCE	COEFF. OF VARIATION	90% CL ACCURACY
1	1	2	6	0.0	0.0	0.0	0.0	0.0	0.000		0.000		
1	0	2	6	208.0	68.4	34.7	29.3	40.1	5.444	0.0673	27.000	0.1499	0.1558
2	1	2	11	17.0	3.9	1.5	0.3	2.8	0.926	0.6227	2.373	0.9967	0.8068
2	0	2	11	99.0	32.8	9.0	7.8	10.2	0.067	0.0287	10.791	0.3650	0.1383
3	1	2	6	12.0	7.1	2.0	0.4	3.6	1.500	0.6124	3.238	0.8997	0.8099
3	0	2	7	45.0	27.1	6.4	4.9	8.0	0.276	0.0816	8.762	0.4605	0.2381
4	1	2	4	6.0	15.8	1.5	-1.7	4.7	4.500	1.4142	9.000	2.0000	2.1137
4	0	2	4	12.0	25.5	3.0	1.1	4.9	0.500	0.2357	6.500	0.8498	0.6322

AVERAGE DAILY PASSENGERS OF FARE CATEGORY = 399.0 OR 24.9 PERCENT OF TOTAL

PASSENGERS OF FARE CATEGORY FOR FIRST DAY = 384.7 OR 24.5 PERCENT OF TOTAL

PASSENGERS OF FARE CATEGORY FOR SECOND DAY = 417.0 OR 25.1 PERCENT OF TOTAL

Figure 4. Report of elderly passengers for route 2.

ALL THE STATISTICS PRESENTED BELOW ARE FOR ELDERLY PASSENGERS

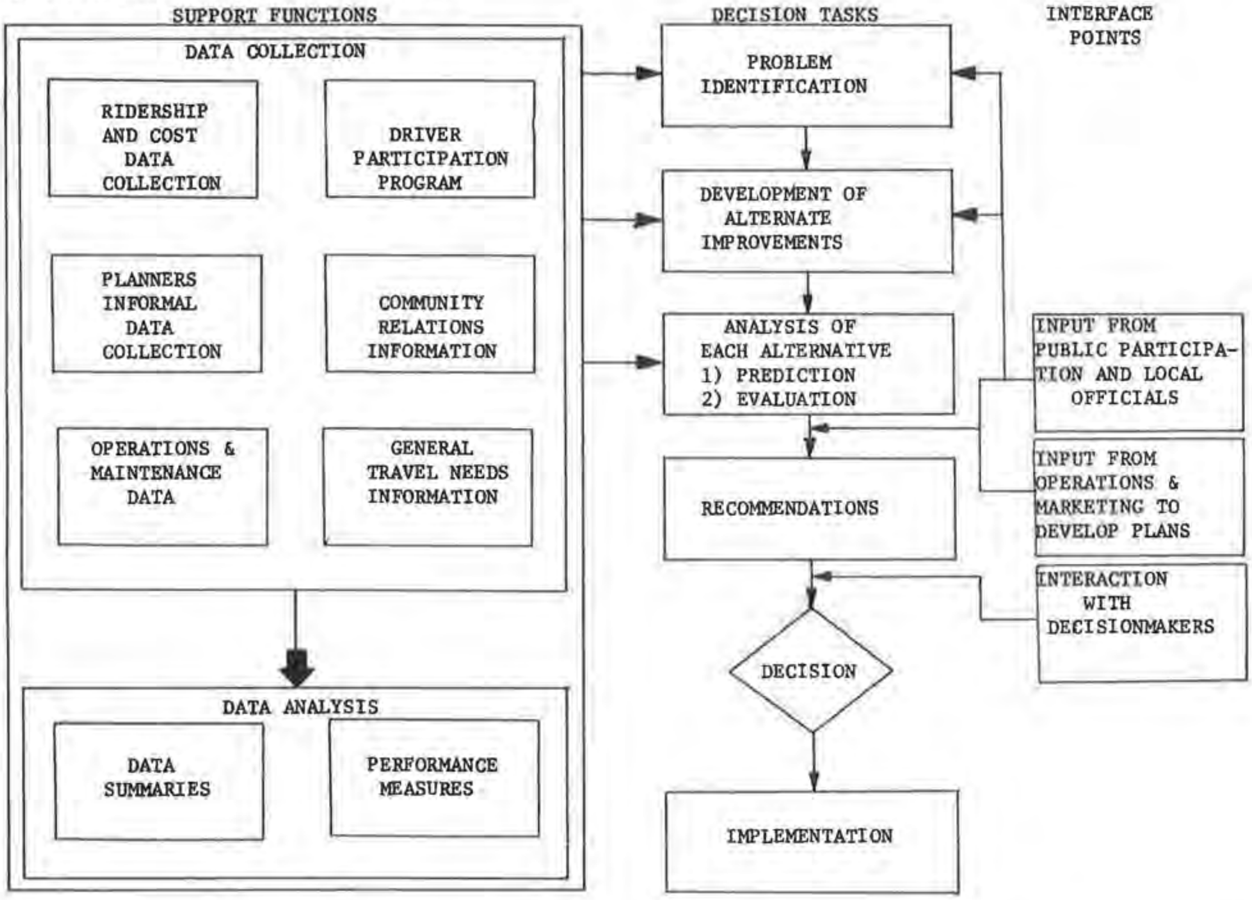
									BETWEEN DAY		WITHIN PERIOD		
TIME PERIOD	DIRECTION	DAYS SAMPLED	DAILY SCHEDULED TRIPS	EXPANDED TOTAL	PERCENT OF TOTAL	AVERAGE PER TRIP	90% CL LOWER BOUND	90% CL UPPER BOUND	VARIANCE	COEFF. OF VARIATION	VARIANCE	COEFF. OF VARIATION	90% CL ACCURACY
1	1	2	6	14.0	9.5	2.3	1.0	3.6	0.444	0.2857	1.333	0.4949	0.5546
1	0	2	6	12.0	3.9	2.0	0.1	3.9	1.000	0.5000	3.000	0.8660	0.9705
2	1	2	11	133.0	30.9	12.1	10.1	14.1	0.159	0.0330	27.236	0.4316	0.1633
2	0	2	11	63.0	20.9	5.7	4.1	7.4	0.754	0.1516	12.800	0.6247	0.2888
3	1	2	6	18.9	11.2	3.1	1.3	5.0	0.983	0.3155	10.667	1.0392	0.5842
3	0	2	7	22.0	13.3	3.1	1.6	4.6	0.412	0.2041	7.619	0.8783	0.4790
4	1	2	4	0.0	0.0	0.0	0.0	0.0	0.000	.	0.000	.	.
4	0	2	4	0.0	0.0	0.0	0.0	0.0	0.000	.	0.000	.	.

AVERAGE DAILY PASSENGERS OF FARE CATEGORY = 262.9 OR 16.4 PERCENT OF TOTAL

PASSENGERS OF FARE CATEGORY FOR FIRST DAY = 275.5 OR 17.5 PERCENT OF TOTAL

PASSENGERS OF FARE CATEGORY FOR SECOND DAY = 250.7 OR 15.1 PERCENT OF TOTAL

Figure 5. Proposed short-range transit planning process.



tive changes be evaluated based on their true expected cost.

As has been discussed earlier, we are not in a position to prescribe the processes to be followed for incorporating these interface points into SRTP. The best approaches to doing this will depend on the capabilities of the transit organization. All we can do is indicate, for the proposed SRTP approach, the steps in which communications with other parts of the agency are important. Figure 5 (10) is a graphical representation of the proposed approach to SRTP, including the interface points with the rest of the organization.

SUMMARY

This paper has explored current practice as it applies to the design of bus services and suggested modifications that might make the planning process better suited to the needs of the transit industry in times of fiscal austerity. Perhaps the most important change suggested is to move away from an exclusive reliance on problem-centered screening of services that require study and possible change. This reliance, which is tied to the widely accepted practice of setting service standards and flagging substandard routes, may mean that the planner does not consider opportunities that may exist for improvement on acceptable routes. For example, strategies such as segmentation of service on a route into express and local portions, establishment of service zones, or having some vehicles deadhead in the lightly traveled direction to improve productivity are never likely to be feasible on problem routes, yet they may be quite useful on high-ridership corridors. By improving productivity on such routes, resources might be made available to better tackle the true problem routes. Thus, a second focus of attention to be added to the problem-centered approach would be an action-centered screening to identify opportunities for improvement on routes where no problems exist. Modifications were also proposed to recognize the multiple objectives that transit operators are striving to achieve and to deal with the problem of presentation of data in forms more directly useful in planning.

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Surveillance and Monitoring of a Bus System

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Most transit operators occasionally conduct an on-board survey of riders. Based on experiences in Washtenaw County (Ann Arbor) Michigan, Dade County (Miami) Florida, and Honolulu, Hawaii, this paper examines three aspects of such surveys. First, a survey instrument is described that permits considerably more information to be collected than is possible from the traditional postcard type of on-board survey. Descriptions of the types of data needed to be collected on the participatory self-administered survey of riders for both systemwide surveillance and individual route monitoring are provided. In addition, it is recommended that the survey personnel record observable information (e.g., passenger volumes) on bus operations. Second, procedures are described for reducing nonresponse bias for collecting at least some information from a subgroup of riders who would otherwise be nonrespondents. Third, sampling strategies (including the necessary sample sizes) are described both for systemwide surveillance and individual route monitoring.

Most transit operators maintain the collection of a certain amount of data about the system, mainly from the perspective of the operation of the system in contrast to data about the system delivery to the actual and potential rider. Data frequently collected include revenue, load profiles (including maximum load points), vehicle hours and vehicle miles of service operated, and a variety of similar operational and financial data. All of this information is necessary to the management of a transit property and provides much needed information on the system performance; however, it is not complete because it does not measure how people use the system and, therefore, who will be affected by system changes and in what way they will be affected.

Most transit operators, from time to time, conduct some form of on-board survey of riders. This survey is typically a brief set of questions on a postcard-size form that is distributed by drivers or survey personnel who ride the buses during the survey. Postcards are usually designed either to be returned on the bus or to be mailed back later. The main drawbacks to this type of survey are the perceived restriction of limiting questions to what will fit on (usually) one side of a postcard and the usually unscientific sampling that is used. Two aspects are of concern with respect to sampling. The first is the lack of application of basic sampling procedures that would lead to near-optimal efficiency in the data collection and will usually reduce considerably the sample sizes needed to obtain data of known and calculable reliability. The second is the problem of nonresponse that occurs in a self-administered survey of this type, and that in this kind of application is generally uncontrolled and provides no information on the biases that may be caused by nonresponse (1).

In this paper, we deal with three aspects of the design of on-board surveys. First is the issue of the amount of information that can be collected. A survey instrument design is described that provides considerably more information than is possible to obtain from the simple postcard survey. Second, procedures for reducing nonresponse through instrument design are described, where these procedures also provide information about a subgroup of nonrespondents and some indicators of the potential biases that may exist. Third, sampling strategies are described for two types of situation. The first context is that of systemwide surveillance, where the desire is to obtain data about all or a large sample of routes that make up the system, but only to a sufficient degree of accuracy to describe systemwide patronage and system use and sufficient to focus attention on routes that may not be performing to the standards desired or required and may warrant further, more detailed, study. The second context is that of individual route monitoring, where the need is to obtain data of sufficient accuracy on a single route to be able to identify changes that occur in patronage patterns as a result of specific changes to the route.

For these contexts, surveillance is defined as the collection of data for systemwide profiles and information, with sufficient detail and accuracy on