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FINAL REPORT

INNOVATIVE ROUTING AND SCHEDULING CONCEPTS FOR TRANSIT SYSTEMS

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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ABSTRACT

The objective of this research was to investigate innovative routing and scheduling concepts to determine how transit systems in Virginia may improve ridership and reduce operating costs. Information on innovative routing and scheduling concepts was obtained through a literature survey, and transit systems in Virginia were surveyed to determine the routing and scheduling concepts in use, transit operating environments, and problems in routing and scheduling.

Five of the innovative concepts evaluated are being recommended for consideration by selected Virginia transit operators. These are (1) a procedure for redesigning transit routes and schedules in small systems, (2) methods to improve short-range transit planning, (3) a timed transfer system, (4) guidelines for a transit-center based transit system, and (5) guidelines for designing transfer policies. These concepts are described in detail in the report.

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TABLE OF CONVERSIONS

	Multiply by	To Obtain
Persons per square mile	0.386	Persons per square kilometre
Passengers per mile	0.622	Passengers per kilometre
Miles per hour	1.609	Kilometers per hour
Miles	1.609	Kilometres
Square feet	0.09	Square metres

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INTRODUCTION AND PROBLEM

A goal of interest to all transit operators is improvement in the efficiency of their operations. On the state level in Virginia, two means for increasing efficiency are (1) to improve ridership and (2) to reduce operating costs. Innovative concepts for improving the efficiency of transit operations have been developed and demonstrated. Routing and scheduling are two key components of operations in which innovative concepts can improve ridership and reduce operating costs. Ridership may be improved or increased by elevating the level of service, more direct routing, reducing waiting time for transfers, providing service to satisfy new travel demands, and improving service reliability. Operating costs may be reduced by eliminating duplicate routes, reducing route travel time, reducing deadheading, and improving the routing structure.

There is a gap between the development of successful innovative concepts and their implementation. Many transit operators do not implement these concepts because they are either unaware of them or, because of a lack of information, they are skeptical of their efficacy.

There are 19 public transportation systems in the Commonwealth of Virginia serving areas ranging from heavily urbanized to rural. Many of these transit operators are affected by the gap between the development and implementation of innovative concepts, and concepts that have a high potential for improving the efficiency of transit operations are not considered.

OBJECTIVE AND SCOPE

The objective of the research reported here was to investigate innovative routing and scheduling concepts to determine how Virginia's transit systems may improve ridership and reduce operating costs. The Public Transportation Division of the Virginia Department of Highways and Transportation requested the research.

The scope of the project is outlined by the following tasks that were conducted.

A. A literature survey to review innovative routing and scheduling concepts and to develop a brief description of each.

B. An inventory of the routing and scheduling concepts used by transit operators in Virginia, transit operating environments, and routing and scheduling problems.

C. A screening of the innovative concepts to select those applicable to transit systems in Virginia.

D. An evaluation of the selected concepts based on their efficacy in improving transit operations and their potential for implementation in Virginia.

E. The development of a program for implementation of the concepts thought to be most useful based on a detailed description of the planning and implementation procedures for the concepts.

The project was limited to consideration of only conventional fixed-route, fixed-schedule operations.

REPORT FORMAT

The remainder of this report is divided into six major sections as follows:

1. Survey of the Literature
2. Inventory of Transit Systems in Virginia
3. Evaluation of the Innovative Concepts
4. A Program for Implementation of the Selected Innovative Concepts
5. Summary
6. Recommendations

The first three sections describe the tasks leading to the development of a program for the implementation of selected innovative concepts, which is described in the fourth, or key section. The recommendations suggest how the implementation program can be made operational.

SURVEY OF THE LITERATURE

A literature search revealed several innovative routing and scheduling concepts. Twelve of these categorized into four groups -- routing and scheduling changes, transfer practices, routing changes, and scheduling changes -- are listed below, for the most part as the title of the publication in which they are described, and then they are described in the form of annotations of the referenced publications.

I. Routing and Scheduling Changes

1. How to Redesign Transit Routes and Schedules in Response to Changing Ridership Trends in Smaller Systems(1)
2. Methods for Service Design(2)
3. Paring Transit Costs(3)

II. Transfer Practices

4. Timed Transfer(4, 5, 6)
5. Transit Operator Guidelines for Transfer Policy Design(7)
6. Planning and Designing Transit Center-Based Transit Systems(8)

III. Routing Changes

7. A Note on Bus Route Extensions(9)
8. Evaluation of Denver RTD Route Restructuring Project(10)

IV. Scheduling Changes

9. Operational Improvements in a Two-City Bus Transit Corridor(11)
10. Improving the Reliability of Bus Transit Service(12, 13)
11. Zone Scheduling of Urban Bus Routes(14)
12. Setting Frequencies in Bus Routes: Theory and Practice(15)

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Routing and Scheduling Changes

How to Redesign Transit Routes and Schedules in Response to Changing Ridership Trends in Smaller Systems(1)

A step-by-step procedure that can be used by any small or medium sized transit system to improve route and schedule design is presented. There are five basic steps: (1) planning an on-board, line count survey to obtain complete load point data and schedule adherence, (2) conducting the survey and tabulating the data, (3) reducing and utilizing the data for analysis, (4) analyzing route and schedule design weaknesses by an analysis team, and (5) presenting an integrated route and schedule redesign that reflects general guidelines and transit management's service objectives. The procedure results in redesigned services that are integrated with the operating environment and based on a comprehensive data base. It is demonstrated in two case studies: (1) to redesign the Bellingham, Washington, transit systems for improved passenger efficiency and (2) to adjust routes and schedules for passenger overloading at a California municipal transit service.

Methods for Service Design(2)

Wilson and Gonzalez propose a short-range transit planning (SRTP) process that identifies not only substandard routes but also acceptable routes that can be significantly improved by service changes. The SRTP process monitors operations and plans service changes for implementation during the next schedule change. In the problem identification task all routes are ranked in terms of the performance measures selected for each goal. The rankings are used to screen the routes that are worst performers in some measures and not good in any single measure as well as acceptable routes that can be improved. In the second task, design of alternatives, detailed alternative changes are developed based on possible actions that will improve the routes. Typical problems and corresponding potential alternatives are identified. The third task is to analyze each alternative by predicting route performance with the proposed change and evaluating the alternatives. The final task is to recommend the most promising alternatives. The most important change is in considering acceptable routes in the problem identification task. This method is applicable in all transit operations. The productivity of the transit system can be significantly improved when service changes are implemented. No case study experience is cited.

Paring Transit Costs(3)

Four categories of actions to reduce or control operating costs and two considerations to increase revenue are described. Actions with no visible detrimental effect to the riding public include (a) fine-tuning running times, (b) minimizing layover time, (c) interlining routes, (d) switching linked pairs, (e) skip-stop schedules on heavy routes, and (f) out-of-service, deadhead opportunities.

Actions involving only minimal inconvenience or temporary displacement are (a) turn back opportunities, (b) increasing vehicle size while reducing service frequency, (c) combining routes which provide essentially similar services, (d) replacing fixed-route service with demand responsive or paratransit operations, and (e) matching headways to realistic ridership demand.

Actions involving minimal service elimination include (a) cutting individual trips or portions of trips, (b) reducing poorly utilized service during times when alternative trips may be possible, (c) analyzing closely the first trip out and last trip in on each route, and (d) viewing weekend service as individual trips.

Actions which involve substantial service elimination and passenger inconvenience should be avoided if possible. Identifying desirable destinations not presently served and considering the establishment of commuter express service are two considerations for increasing revenues.

It is noted that a medium-size East Coast transit system reduced operating costs by $450,000 and experienced an increased ridership of 20% over the next three years by paring transit costs. Similar results were experienced by a medium-size West Coast transit system despite a fare increase.

Transfer Practices

Timed Transfer Systems(4, 5, 6)

Timed transfer is a coordinated network where several transit lines converge at a transit center or transfer point at the same time, thus enabling passengers to transfer between any two lines.(4) Timed transfers are being used to provide transit service in areas where transit demand is too low to support high levels of conventional transit service, to attract new riders, and to extend service into new areas. There are basically three types of timed transfer systems: simple timed transfer (2 routes at 1 transfer point), pulse scheduling (more than 2 routes at 1 transfer point), and multiple focal point timed transfer (more than 1 transfer point). Timed transfer appears to be applicable where there are (1) dispersed origin-destinational patterns, (2) medium population density (1,000 to 10,000 persons per square mile), (3) uniform demand density, and (4) headways greater than 15 minutes.(4,5)

Ridership increases of from 5% to 12% may be realized under some circumstances from the implementation of timed transfer.(6) Overall, timed transfer appears to be a cost-effective method of increasing ridership and service in many operating environments without necessarily increasing costs.

A timed transfer system planning procedure developed by Vuchic consists of four phases: initial planning, analysis and preliminary planning, final network planning, and final operations planning.(4)

Timed transfer systems are operational in numerous cities, including Ann Arbor, Michigan, Boulder, Colorado, and Portland, Oregon. Transit centers and holding strategies have been integrated into timed transfer systems.

Transit Operator Guidelines for Transfer Policy Design(7)

The objective of this report is to assist the transit operator in choosing a transfer policy that best meets local goals and objectives. Eleven transfer policies or components and their current utilization are described. The demand-side (user-satisfaction, revenue, ridership) and supply-side (costs/operations) consequences are summarized for the alternative transfer policies. Also, the trade-off between expected benefits and costs of implementing a specific policy, implementation on constraints, and the operating environments in which the different policies are applicable are described. Seven of the eleven policies are grouped in routing and scheduling options as follows:

A. Routing Options (focus on special placement of routes and transfer walk distances)

1. distance between routes at transfer points

2. through routing

B. Scheduling Options (focus on the timing of vehicle movements with the goal of reducing waiting times)

3. schedule coordination

4. dynamic control of departure times at transfer points

5. timed transfers

6. schedule adherence on connecting routes

7. service frequency on connecting routes

The guidelines may be used by an operator of any size system to determine which policies may be beneficial or to identify policies that may produce particular types of effects.

Routing Changes

Planning and Designing a Transit Center-Based Transit System: Guidelines and Examples from Case Studies of Twenty-two Cities(8)

Transit centers are interchange facilities typically located in suburban areas at or near major activity centers or in a central business district and serve as a focal point for high levels of transit service. The transit center concept is examined in this report to determine if and how it can be implemented to improve the efficiency and effectiveness of transit service on an areawide basis. A planning framework is developed to assist in the design of transit centers. Transit centers range from a simple on-street bus stop with a shelter (i.e., a major transfer point) to a large-scale, multimodal center. Transit centers may be located downtown, on freeways, or off-street in suburban areas. This range in the types and locations of transit centers makes transit centers applicable in all transit operating environments.

A Note on Bus Route Extensions(9)

Ten route extensions were examined in Albany and Rochester, New York, to investigate the conditions that provided viable bus route extensions. The factors examined were ridership generated, length and frequency of service, type and size of the new population served, and additional operating expense. A simple revenue/cost model ratio of the change in revenue to the change in cost which is equal to the product of the change in ridership and average fare divided by the product of the change in vehicle-miles and the average cost per vehicle-mile was used. The conclusions confirm conventional wisdom that route extensions that are most likely to be successful have one or more of the following characteristics: they are short, serve a dense area of concentrated employment or residences, and do not increase main route headway. These characteristics may serve as a guide for the development of a route extension.

Evaluation of Denver RTD Route Restructuring Project(10)

To provide better bus service for more people through a modernized, simplified transit system, the Denver Regional Transit District (RTD) restructured its system from a radial to a more grid-like network. The restructuring, perhaps the most comprehensive restructuring of bus rates by a major transit property, was done in two steps rather than a series of incremental improvements. Transit centers and timed transfer were incorporated in the restructured system.

There was an estimated long-term ridership decrease of 3%. The Denver RTD primarily serves transit-dependent riders in an auto dominated area. The ridership decrease was offset by an 18% increase in the average fare. The potential market for transit may be smaller than expected. More riders than not perceived an increase in all components of trip time. There was a 15% increase in the average unit time due to schedule reliability problems. The on-board travel time for the typical transit trip was unchanged. There was an increase in the number of buses in service and a 2.2% increase in route miles. The increase in operating costs was about 1.7%.

The objectives of increasing the level of service and simplifying the route structure, and of distributing service more equitably appear to have been achieved. However, the objectives of improving transit travel time, increasing the operating efficiency of vehicles and drivers, and increasing transit ridership were not achieved.

The following conclusions were drawn: (1) it is possible to make radical, comprehensive changes in existing transit services in a quick transformation and maintain strong public support, (2) an intensive planning and public information program is required for comprehensive changes, and (3) significant short-term disruptions are to be expected.

Scheduling Changes

Operational Improvements in A Two-City Bus Transit Corridor(11)

An analysis of the most heavily used corridor in the Capital District Transportation Authority's service area, N. Y. Rte. 5 from Albany to Schenectady, N. Y., is discussed. Four problems are explained.

The need and justification for additional express service was analyzed using cost and revenue comparisons of AM and PM express runs and local runs. The capital-operating cost trade-off needs to be carefully studied if articulated buses are considered for overload problems.

There were two problems with through and local service coordination: (1) schedule check points were too tight for through service, and (2) the average loads were higher for the through buses. Additional scheduling time and changing intermediate control points improved the first problem and changing the phasing of through and local buses improved the second. Previously, terminal departure times for the through buses were set for major work-leave times and the local buses preceded the through buses by 5 minutes. The departure times for local buses were shifted up 5 minutes to put them in the prime position for picking up workers. This reflects the principle that the absolute schedule timing of coordinated services is at least as important as the relative phasing.

The fourth problem focused on schedule delay, which averaged from 2 to 6 minutes, and its standard deviation, which was 1 to 2 times the delay. This large variance could not be solved by scheduling adjustments but could be solved by improvements in traffic operations. A reasonable rule is that average lateness and the standard deviation in arrivals should be equal.

The insights into these problems may be helpful in the analysis of similar problems.

Improving the Reliability of Bus Transit Service(12, 13)

The level of service measure most clearly related to reliability, that is, variability over time, is travel time. Non-adherence to schedule yields uncertain arrival times, increased waiting times, and transfer difficulties for transit riders, and reduced productivity and increased costs for transit operators. Several control strategies serve to prevent or alleviate reliability problems. Some of the strategies were tested in simulation experiments of a transit corridor in Cincinatti.

In a schedule-based holding strategy, no vehicle leaves a time point before its scheduled departure times. This strategy can be useful on routes with frequencies of less than 10 buses per hour.(12) The major problem of poor connections at transfer points may be significantly reduced by schedule-based holding.

The objective of a headway-based holding strategy is to minimize a weighted sum of wait-time savings due to reduced headway variability and expected delay due to the holding strategy.(12) This strategy is applicable where service is quite frequent, such as headways of 10 minutes or less, and is a solution to the bunching of vehicles. The relative benefits of holding depend on the coefficient of variation of headways, the correlation coefficient between successive headways, and the proportion of total passengers who must ride through the control point. Two headway-based holding strategies, prefol policy, which splits the difference between the preceding and following headways for each vehicle and requires vehicle monitoring, and the less expensive and less reliable single-headway policy, which depends on the current headway and previous hold based on statistical expectation of the following headway, appear effective.(12)

Increasing bus stop spacing reduces travel time and consequently increases the average walking distance. The reductions in travel time, mean waiting time and standard deviation of waiting time were not statistically significant.

Based on simulation experiments, traffic signal preemption has the potential to significantly improve average speed and reliability, and the mean signal preemption is most effective for frequencies of from 10 to 30 buses per hour. Reserved bus lanes combined with signal preemption appear potentially effective, especially for high frequency situations (more than 30 buses per hour).

Other routing and scheduling strategies to improve reliability include limiting through-routes and deadheads, permitting short turns, leap frogging, and developing contingency schedules.(13)

Zone Scheduling of Urban Bus Routes(14)

In zone scheduling, each bus on a route is allocated to a zone where it serves all stops within its zone and all of the buses serve the peak-load point at the end of the route. Zone scheduling is designed for routes with a heavy ridership demand to a single trip end. It reduces travel time since a portion of the route is traveled nonstop and increases productivity by reducing round-trip times and empty seat miles. The disadvantages of zone scheduling are that the frequency of service is reduced relative to all stop service, and local trips across zone boundaries require a transfer.

A dynamic programming formulation that determines an optimal zone structure and vehicle allocations with modest computational requirements is presented in the paper. The objective function minimizes the total wait and travel time summed over all zones subject to available fleet size, sufficient capacity, and minimum frequency constraints. A computer program is given.

The model was applied to a route of the Chicago Transit Authority and the optimal zone structure appeared to be relatively independent of the number of buses used for the service. The effectiveness of zone scheduling depends greatly on the express and local speeds, variability in travel times for express and local links, and the proportion of the total route ridership that has a trip end at the terminus.

Zone scheduling appears most effective for frequencies of from 10 to 30 buses/hour, given suitable origin-destination patterns and a parallel express facility. It may be effective for frequencies less than 10 buses/hour if most passengers are destined to one terminus. A parallel expressway improves the effectiveness of this strategy.

Turnquist recommends further research to incorporate intermediate steps for evaluating the transfer penalty and exploring the relationship between zone scheduling and skip-stop operations.

Setting Frequencies on Bus Routes: Theory and Practice (15)

A model was developed (1) to overcome the inadequacy of standards that focus on upper and lower bounds for setting frequencies without considering the need to maximize efficiency within the constraints of the upper and lower bounds, and (2) to fill the need for an accurate model that has simple data and application requirements, that permits frequent usage and that focuses on small changes.

In the model, available buses are allocated between time periods and routes to maximize net social benefit subject to subsidy, fleet size, policy headways, and loading constraints. Equal ratios of marginal benefit to marginal cost for each route yield an optimal allocation. An algorithm to solve this nonlinear program was developed and can be applied with a small computer with some simplifications with a programmable calculator. The case study application was for one garage of the Massachusetts Bay Transportation Authority and included 15 routes. The paper recommends an allocation plan that would reduce the number of buses operating, and consequently the deficit, while improving ridership and waiting time. The model is also useful in policy analysis such as examining the benefits of increasing bus capacity. The most important limitation of the model, the assumption of independence of all routes, can be incorporated in the objective function to some degree. The paper identifies areas needing further research.

INVENTORY OF TRANSIT SYSTEMS IN VIRGINIA

A survey was conducted of all transit operators in Virginia to identify routing and scheduling concepts used and problems and concerns.

Transit systems were grouped based on the operating environment based on system size, service area, and route and schedule structure.

Survey

The results of the survey are shown in Table 1. Fourteen of the 19 operators (73.7%) responded to the survey. One respondent was omitted since the operation had a maximum frequency of 1 round-trip per day and was, therefore, not a conventional fixed-route, fixed-schedule operation. Another respondent was omitted because the survey form was incomplete. Therefore, the survey represents the responses of 12 operators (63.2%).

One-half of the systems have goals and objectives relative to routing and scheduling (e.g., to provide at least 30-minute headways on all routes). Two-thirds of the systems have service standards which vary from 1 performance measure, such as schedule adherence, to 14 performance measures that comprehensively address transit operations.

Five of the six transfer policies acknowledge transfers as an important element of the transit system. Five systems practice timed transfer and schedule coordination. It appears that the systems practicing schedule coordination view their practice as a partial timed transfer operation since 10 systems noted the implementation of timed transfer.

The route structures are basically radial. Ten systems serve small urban areas, with half being timed transfer-based systems. The multifocal systems serve more than one municipality.

Four routing and scheduling problems were noted by 3 or more transit operators: overlapping routes, need to change headways, uncoordinated transfers, and the need to extend routes. Overlapping routes are common where several routes converge at one location such as a central business district.

Transit System Grouping

It was desirable to establish transit system groups in order to match the transit operating environments with the innovative concepts that are appropriate for a given environment. The service area, system size, and route structure for transit systems in Virginia are shown in Table 2. These systems were grouped by service population, system size, and route structure. The route structure grouping shown in Table 3 was selected because it appeared most appropriate for identifying the applicable concepts.

Table 1

Survey Results
Responses of 12 transit systems

1. Does your transit system have goals and objectives relative to the routing and scheduling of buses? 6 yes 6 no

2. Does your transit system have service standards? 8 yes 4 no

3. a) Transfer policy

direct service to downtown, transfer service crosstown (one system also included direct service to a university)	3
transfers are possible anywhere	2
transferring is discouraged	1
provide ease of transfer wherever possible	1

   b) Transfer practice

schedule coordination	5
timed transfers at the CBD (one is at a university)	3
timed transfers at 2 or more locations	2
no stated policy or practice	2

4. Routing and scheduling concepts that have been implemented

a) timed transfer	10
b) redesigned schedules	7
c) redesigned routes	6
d) pulse loops (timed transfers between loops traveling in opposite directions)	1
e) other (automated scheduling)	1

5. Route structure

a) timed transfer-based radial system	5
b) small urban radial	5
c) medium-size urban radial	1
d) multifocal	3

6. Routing and scheduling problems

a) overlapping routes	5	i) excessive deadheading	1
b) need to change headways	4	j) service unreliability	1
c) uncoordinated transfers	3	k) multiple branches on 1 route	1
d) need to extend routes	2	l) delays due to congestion, railroad crossings, draw bridges	1
e) need to truncate routes	2		
f) need to add new routes	2		
g) slow speeds	2		
h) overcrowding	2		

Table 2

Transit System Operating Characteristics

Transit System	Estimated Service Area (pop. 1980)	Estimated Service Area (square miles)	System route-miles	Size (number of buses)	Route Structure
Harrisonburg City Bus Service	19,300	6.0	5	3	timed transfer at 2 points, 3 loops
James City County Transit	22,513	148.0	21	5	2 radial routes, timed transfer at CBD
Winchester City Transit	23,100	9.3	52	11	timed transfer at CBD, 3 through-routes
Staunton Transit Service	25,000	10.0	43	8	timed transfer at CBD, 2 radial, 2 paired routes
Blacksburg Transit[1]	31,000	17.9	29.7	14	timed transfer at university 2 through routes, 1 loop
Charlottesville Transit Service	42,000	12.4	75	15	radial system, 5 through, 1 radial, 2 crosstown routes
Danville Bus Service	45,832	16	75	10	radial system, 5 through routes
Bristol City Bus System	45,858	12.5	53	16	radial system, 5 radial routes, 3 loops
Petersburg Area Transit Service	70,000	23.1	71	14	timed transfer, 2 through, 4 radial routes

Table 2 (continued)

Transit System	Estimated Service Area (pop. 1980)	Estimated Service Area (square miles)	System route-miles	Size (number of buses)	Route Structure
Greater Lynchburg Transit Co.	68,000	50.2	11.5	27	radial, 12 paired routes
Greater Roanoke Transit Co.	99,000[2]	43.1	194	50	radial, 8 paired, 1 radial route
Greater Richmond Transit Co. (GRTC)	220,000[2]	145	359	212	radial
Peninsula Transportation District (Pen Tran)	271,000	122	273	118	bifocal radial
Tidewater Transportation District (TRT)	760,000	450.3	450	172	multifocal
Washington Metropolitan (WMATA)	828,700	452.7	486	573	multifocal

[1] Information obtained from Blacksburg Transit

[2] Service area population outside of the central city (or for WMATA, Virginia) is not included

Source: Reference 16 and system maps

Table 3

Transit System Groupings by Route Structure

Timed Transfer-Based Radial System	Small Urban Radial	Medium-Size Urban Radial	Multifocal
Harrisonburg	James City	GRTC	Pen Tran
Winchester	Charlottesville		TRT
Blacksburg	Danville		WMATA
Staunton	Bristol		
Petersburg	Roanoke		

EVALUATION OF THE INNOVATIVE CONCEPTS

This task was the last of the three leading to a program for implementing selected concepts. The evaluation of the concepts was based on their efficacy in improving transit operations and their potential for implementation in Virginia. The three phases of this task were screening, evaluation, and selection of innovative concepts.

Screening of Innovative Concepts

The innovative concepts were screened to limit the number to be considered in the evaluation. Three criteria were used.

a. The concept is applicable for transit operating environments in Virginia.

b. The concept is easy to understand and requires a level of technical expertise available within most transit systems.

c. The concept has a procedure for implementation where the scope is more than a case study of lessons learned.

Out of the 12 concepts reviewed, the following 6 remained after the screening.

1. How to Redesign Transit Routes and Schedules in Response to Changing Ridership Trends in Smaller Systems

2. Methods for Service Design (SRTP)

3. Timed Transfer

4. Transit Operator Guidelines for Transfer Policy Design

5. Planning and Designing Transit Center-Based Transit Systems

6. Improving the Reliability of Bus Transit Service

Evaluation

Ideally, an evaluation should be performed for a particular transit system to obtain quantitative performance measures and a subjective evaluation for a specific operating environment. However, the evaluation of innovative concepts for transit systems in Virginia used general terms and was basically a subjective assessment. Quantitative performance measures are not available for the innovative concepts. The evaluation consisted of three parts: (1) an assessment of the ability of the concepts to address the problems of transit systems in Virginia, (2) an assessment of the applicability of the concepts to transit groups by route structure, and (3) a ranking of the concepts.

Problems of Transit Systems

The ability of the innovative concepts to address the routing and scheduling problems identified in the survey is displayed in Table 4. The innovative concepts that analyze and plan route and schedule structures -- that is, those that redesign routes and schedules for small transit systems and those that provide methods for service designs -- are comprehensive in addressing the problems. The literature on timed transfer deals comprehensively with the problems peculiar to this system. The remaining concepts address specific problems.

Applicability to Transit Groups

All of the innovative concepts are applicable for all of the transit groups based on route structure. The concept on redesigning routes and schedules for small transit systems can be used on larger systems by sampling bus runs for the on-board survey, examining a subsection of the service area, or doing both. Larger transit systems will require more extensive data collection, analyses, and planning than the smaller systems for all of the innovative concepts.

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Table 4

Evaluation with Respect to Problems
of Transit Systems

PROBLEMS	INNOVATIVE CONCEPTS					
	Redesigning Small Transit Systems	Methods for Service Design	Timed Transfer	Transfer Policy	Transit Center	Improving Reliability
overlapping routes	x	x	x[a]			
need to change headways	x	x	x[a]			
uncoordinated transfers	x	x	x	x	x	
need to extend routes	x	x	x[a]			
need to truncate routes	x	x	x[a]			
need to add new routes	x	x	x[a]			
slow speeds	x	x	x[a]			x
overcrowding	x	x	x[a]			
excessive deadheading	x	x	x[a]			x
service unreliability	x	x	x[a]			x
Total	10	10	1(10)[a]	1	1	3

Note: An "x" indicates that the problem is addressed by the concept.

[a]These problems are addressed for timed transfer systems only.

Ranking of the Innovative Concepts

Members of the project advisory committee, which included representatives of five transit systems, were sent a questionnaire on the possible use of innovative concepts. The members were asked if they would use an innovative concept and to rank the concepts in order of their importance. The concepts were ranked in the following order by the committee.

1. Redesigning routes and schedules for smaller systems
2. Planning and design of a transit center-based transit system
3. Methods for service design
4. Timed transfer systems
5. Guidelines for transfer policy design
6. Improving transit service reliability.

With the exception of transit center planning and design of a transit center-based transit system, the ranking of concepts is consistent with the comprehensibility of the concepts in addressing problems of routing and scheduling.

Selection of Innovative Concepts

The five highest ranked innovative concepts were selected for the implementation program. The transit service reliability strategies were omitted because of (1) a lack of experience with the strategies, and (2) a lack of clear, significant impacts resulting from their use.

A PROGRAM FOR IMPLEMENTATION OF THE SELECTED INNOVATIVE CONCEPTS

The implementation program is the key element of this report. The innovative concepts are described in detail, and, if available, the planning and design procedures are outlined. The recommendations for implementation are made in three steps: (1) the functions and applicability of the concepts, (2) recommendations for solving problems experienced by transit systems in Virginia, and (3) recommendations for consideration of innovative concepts by transit systems in Virginia. The costs for planning, implementing, and operating the innovative concepts are discussed. A procedure for periodically updating the list of recommended innovative concepts is provided.

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How to Redesign Transit Routes and Schedules in Response to Changing Ridership Trends in Smaller Systems

The purpose of this concept is to provide transit management with a method for the survey, analysis, and redesign of a transit system to improve passenger service. The scope of the on-board, line count survey is the following: for smaller systems with 1 to 6 buses per hour per route, a sample of all operational hours on all routes; and for larger systems with 7 to 12 buses per hour per route, a sample for all routes during peak hours only. There are five basic steps in the procedure as discussed under the following subheads.

Step 1. Planning the On-board, Line Count Survey

Information on the scheduled bus runs should be obtained from headway or driver assignment sheets. The observers may be assigned to the driver in smaller systems where the driver operates the same route during the day. In larger systems, the observer may generally be assigned to a vehicle if drivers are switched on a route or to a series of trips if vehicles are switched.

It is recommended that a supervisor or dispatcher assist in the scheduling of observers. Generally, one observer surveys the morning shift while another surveys the afternoon shift. If buses are added during the peak hours (trippers), then observers should be scheduled to work split shifts whenever possible. Normal operating days should be surveyed.

Since it is not recommended that transit personnel be observers due to the expense and possible scheduling problems, observers can best be found by offering the minimum wage rate for part-time, temporary employment. Suggested recruits are students, senior citizens, housewives, and members of civic groups and social agencies or programs.

Training and supervision are extremely important to ensure the accuracy and validity of the data collected. The survey supervisor should be a line supervisor, dispatcher, extra-board driver, or someone with similar experience. The functions of the supervisor are (1) to conduct a test run to make certain that each observer understands how to conduct the survey, and to determine the amount of data that can be completed accurately; (2) to assure that the observers report to work on schedule; (3) to notify all affected bus drivers of the survey and request their assistance, if necessary, in counting boarding passengers during peak hours and answering questions about bus stop locations (and possibly to introduce the observer to the driver); and (4) to collect, check, and order the completed survey forms each day. The observer should sit in the side seat directly behind the driver and should synchronize his watch with the driver's or survey supervisor's.

Departing passengers may be counted as they stand up to prepare to depart. In most cases, it is advisable to request assistance from the driver in counting passengers using the front door when there are standing loads.

The method for tabulating the data, whether manually or by computer, should be decided upon and planned. As compared to manual methods, the use of a computer reduces human error and the time required to tabulate the survey data. Disadvantages are (1) the availability and cost of computer services, and (2) writing the computer program for the basic tasks of summing and sorting the data and printing the results. If an on-board, line count survey will be conducted periodically (e.g., every 2 years), then the computer tabulation option should be strongly considered.

Step 2. Conducting the Survey and Tabulating the Data

The on-board, line count survey form is shown in Figure 1, where most of the data items are self-explanatory.

The data tabulations consist of two steps: (1) tabulating data from the survey forms into totals for each stop, and (2) ranking the stops by use based on passenger count and percentage of passengers and listing them in descending order. The table in Figure 2, the survey summary form, displays the data to be listed with the omission of the columns for bus stop (location) and trip attractors.

Step 3. Reducing and Utilizing Data for Analysis

The basic tool of analysis for the redesign of routes and schedules is the survey summary form shown in Figure 2. Part I, operation analysis, is provided in Figure 3 for all routes. Figure 4 may be used to calculate the total bus miles and hours on each route for the bus trips surveyed. Part II of the survey summary from, Figure 2, is provided by the ranking of bus stop tabulations. The bus stop location and trip attractors (e.g., residential, downtown, middle school, transfer, etc.) are added to this. The trip attractors may be identified by a senior bus operator. Part III of the survey summary form is provided in the survey tabulation totals. If done by the computer, the printing of Figure 2 with Parts II and III completed should be considered in the program.

Ridership by bus stop may be displayed on route maps. This display aids in identifying stops and route segments with high and low passenger loadings. A decision must be made on the total percentage of ridership to be used for route redesign. For example, the bus stops where 65% of the riders board can be denoted by a circle, then a square may be added to these stops to identify where 80% of the riders board. Graphs indicating the number of passengers boarding, alighting, and inside the bus at each stop may also be prepared.

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Line/Route [ ] Run No.: ________ Bus No. : ___________ Destination: _______________

Trip Sequence:* [ ]

Date: ____________ Day of Week: ____________ Time From: __________ AM PM To: __________ AM PM

Observer: ______________ TOTALS:* On: [ ] Off: [ ] Trip Time [ ] Max. Load: [ ]

Survey Conditions: ______________________ (1) ____ (2) ____ (3) ____ (4) ____

SEPARATE ENTRIES AND/OR PAGES BY LINE/ROUTE AND DESTINATION

Bus Stop No.	BUS STOP (Intersection of)	BUS PASSENGERS			DEPARTURE TIME AM-PM		+ (Early) − (Late)	OTHER SURVEY DATA			
		On	Off	Inside	Act.	Schd.		(1)	(2)	(3)	(4)
	&										
	&										
	&										
	&										
	&										
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PAGE TOTALS											

*See instructions

Figure 1. On-board line count survey worksheet. (From reference 1.)

Instructions for On-board, Line-count Survey -- Figure 1
Most data items are self-explanatory

OBSERVER:

1. Survey conditions -- note any condition that may cause a delay, such as weather, traffic (accidents), or unusual circumstances.

2. Bus stop number and/or location -- these may be typed or printed on the form in advance to save time. The bus stops should be numbered for computerized tabulations using the following method: (a) assign a number to every bus stop in the system; (b) inbound and outbound stops across the street from one another should be grouped together (e.g., 23-186).

3. Passengers On-Off-Inside -- if no passengers board or depart the bus, then no data entry is required.

4. Departure time is entered for established time points only. The schedule departure times may be typed in prior to the survey, or entered in after the survey.

5. Other survey data required, such as method of payment, passenger type, transferring passenger, are to be noted at the top of the desired column.

SUPERVISOR:

The data items marked by an * may be completed by the observer if the dry run indicates that he can complete them or, otherwise, by the supervisor.

1. Trip sequence -- this is the trip order taken from the transit system's headway sheet or route schedule.

2. Totals -- the totals may also be calculated by computer tabulation.

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Dates From: ______________ To: ______________

Line/Route ______________________________ Time Period Covered From: __________ AM PM To: __________ AM PM

No. Buses Scheduled: ________

Area Served: ____

I. Operating Analysis (See Figures 3 and 4)

PASSENGERS PER MILE	PASSENGERS PER HOUR	SCHEDULED RUNNING SPEED (MPH)	SCHEDULED HEADWAY (MIN'S.)

II. Line Count (See Figure 1)

Total Ridership (Passengers boarded) ____________ Average Trip Time ________ Scheduled-Trip Time ________

Total Passengers (Boarded & departed) ____________ Maximum Load ________

NO.	BUS STOP	No. Pass's. On	No. Pass's. Off	% Total Pass's. (Ranked)	% Cumulative Total	Trip Attractors

III. Additional Data Summarized (1) - (4)

(1) : ____

(2) : ____

(3) : ____

(4) : ____

Figure 2. Operational analysis and line count survey summary. (From reference 1.)

Time Period From: __________ AM PM To: __________ AM PM Base_____ Peak _____ Base/ Peak _____ Date: __________

SCHEDULE DATA													SURVEY DATA					
Line/ Route	Trip Miles			Trip Time (Min's.)		Run Speed (MPH)	No. Buses	(Min's.)		Bus Cap. (Avg.)		Total Pass's. Brded.	Total Bus * Miles	Total Bus * Hours	Pass's. Per Mile	Pass's. Per Hour	
	Line	Loop	Total	1-W	RT.			1-W	2-W	Seat	Stdg.						

*Refer to B-1 (Bus Hour/Mile Computation) -- Figure 4

Notes:

Loop — route section where bus travels from origin to destination to origin or different streets

1W — one-way

RT — round-trip

2W — headway range for 2-way loops

Figure 3. Operational analysis by line/route. (After Derbonne, reference 1.)

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Line/Route: ______________ Time From: ________ AM PM To ________ AM PM Date: ______________

Trip Sequence	Run No.	Scheduled in Service	
		Miles	Minutes
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
Sub Total			
		Hours	

Trip Sequence	Run No.	Scheduled in Service	
		Miles	Minutes
31			
32			
33			
34			
35			
36			
37			
38			
39			
40			
41			
42			
43			
44			
45			
46			
47			
48			
49			
50			
51			
52			
53			
54			
55			
56			
57			
58			
59			
60			
Sub Total			
		Hours	

TOTAL: Miles ________ Hours ________

Note: Deadhead time should not be included in bus hours.

Figure 4. Bus mile/hour computation.
(After Derbonne, reference 1.)

Transit ridership by bus trip, to be graphed on Figure 5, trip ridership detail, provides a good visual display of the significance of peak hour ridership. Peak periods are identified in the base/peak hour analysis. This figure could be used to screen runs with low riderships for improvements or reductions in service.

If passenger overloading is occurring, and the bus stops where overloads occur for each route have been identified, then an analysis can be made using Figure 6, selected passenger loading by bus stop. This analysis should be performed by a person familiar with transit scheduling and can be conducted as part of the on-board survey. It will define the scope of the overload problem.

Step 4. Analysis of Route and Schedule Design Weaknesses

An analysis team should consist of at least two people: one knowledgeable of the transit system's daily operations and one familiar with transit operations in general but not the system being analyzed. The latter person should provide the team objectivity, a broad range of alternatives, and possibly new approaches to the problem.

Problems in redesign result when routes and schedules have been analyzed separately rather than as a part of an integrated transit network. The problems or weaknesses include route duplication, long trip travel times, and uneven scheduling. Some problems to identify are (1) one-way service, which is inconvenient to the passenger; (2) non-clocked headways (scheduled routing times are not the same every hour), which are inconvenient and confusing; (3) routes on outside perimeter streets, which do not provide the best coverage of the service area; and (4) scheduling of slow average running times, which is inefficient and inconvenient. Any additional problems based on service standards and transit management concerns should be identified.

Step 5. Presenting an Integrated Route and Schedule Redesign

Since the analysis has identified the design weaknesses, this fifth step develops an integrated route and schedule redesign to combat them. It is important that transit management goals and transit service objectives be incorporated in the redesign.

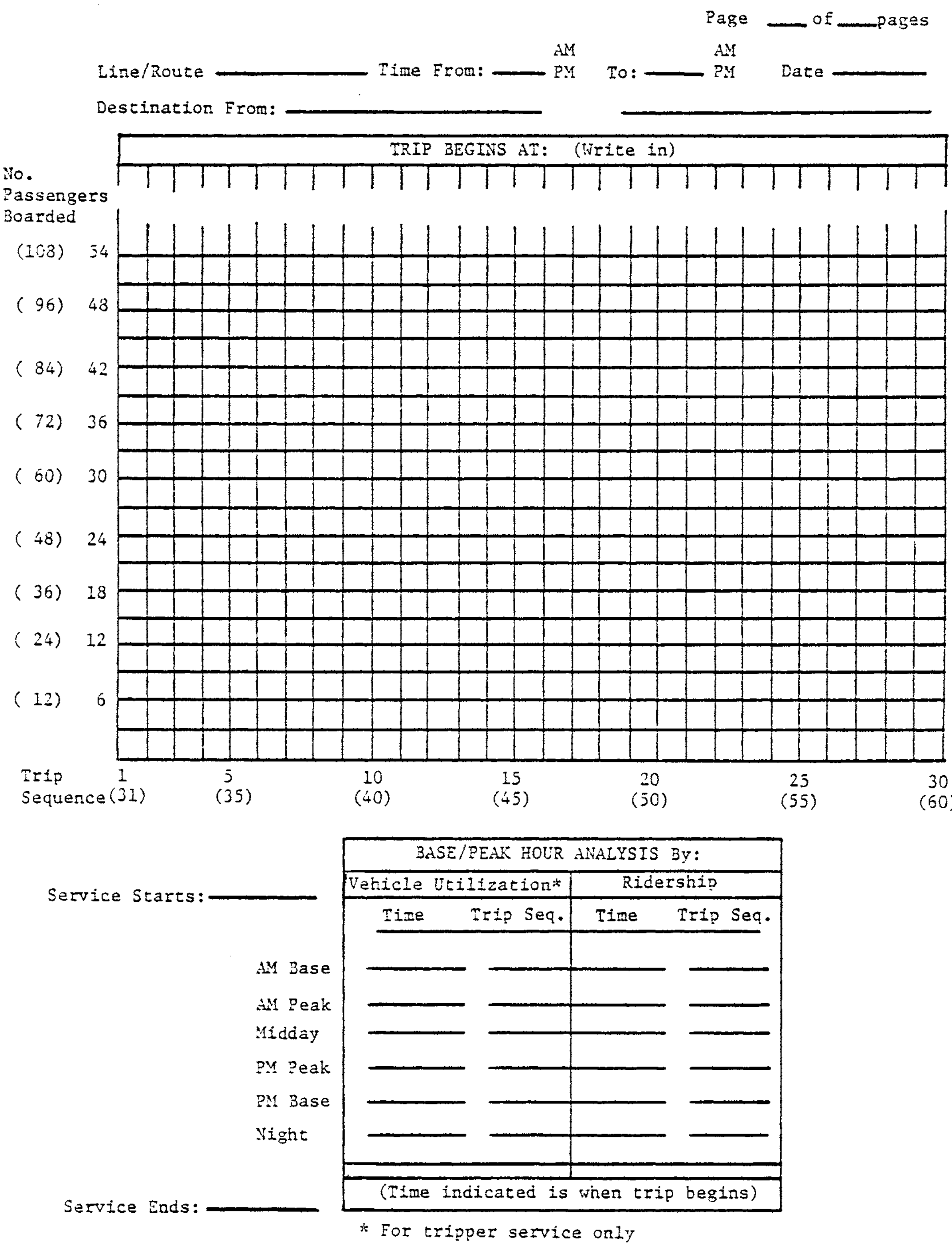

Figure 5. Trip ridership detail.
(After Derbonne, reference 1.)

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Destination From: ______________ To: ______________

Line/Route ______ ______ Principal Streets: ______________

______ ______ ______________

Time From: ______ A.M. P.M. To: ____ A.M. P.M. Dates: ______________

SELECTED STOPS
(Intersection of)

1ST. ______________ & ______________
2ND. ______________ & ______________
3RD. ______________ & ______________
4TH. ______________ & ______________
5TH. ______________ & ______________
6TH. ______________ & ______________

STOP NO.	MAX. LOAD

PASSENGER LOADING

RUN NO.	BEGINNING DEPART TIME ☐ STOP	PASSENGERS INSIDE BUS						ENDING DEPART TIME ☐ STOP		TRIP TIME	+EARLY -LATE	HEAD-WAY
		1st Stop	2nd Stop	3rd Stop	4th Stop	5th Stop	6th Stop	ACTUAL	SCHED.			

Figure 6. Selected passenger loading by bus stop (passenger overload analysis). (After Derbonne, reference 1.)

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Instructions for Passenger Overload Analysis -- Figure 6

1. The overloaded stops may be grouped into sections of the route and order of travel, beginning with the first overloaded stop and ending at the stop where the overload ends.

2. If more than six stops are needed, the selected stops may be alternated, or time points only may be used. If more than one bus route operates on the route segment overloaded, then data for each route may be entered on the same form.

3. The beginning departure time should be one of the first three stops that is a time point. If none of these are time points, then a stop number should be indicated in the block and the time estimated. The same procedure is used to identify the ending departure time using stops 4 through 6.

4. The trip time is the number of minutes elapsed from the beginning departure time to the ending departure time.

5. Headway is the difference in actual ending departure times between two bus runs. The passenger overload analysis should be performed by a person familiar with transit scheduling.

The following design guidelines that are related to the problems discussed in the analysis should be used for the redesign.

1. Route lines should be laid within a half mile of one another whenever possible to provide the quarter mile bus stop distance which is the goal of most transit systems. In most street patterns this implies "splitting the middle" rather than establishing routes on outside perimeters.

2. For smaller systems it is very important that the route lines touch directly on shopping centers and schools.

3. Whenever possible, routes should be laid out in straight lines or, to some degree, zigzag patterns rather than loops.

4. Whenever possible, routes should be combined--as fewer routes in the system network simplify the operations and the use by the public. For example, it is usually preferable to have two 1-1/2 hour straight-line routes rather than three 1 hour loop routes.

5. Whenever a loop configuration seems to be the only solution for providing service area coverage, it should be bidirectional. The bidirectional loop is expensive since buses have to be utilized in increments of two. In addition, there will be complicated frequencies depending upon location and direction of travel desired on the loop.

6. If one-way loops must be used, they should be limited to turnarounds of no more than 10 or 15 minutes for the purpose of passenger convenience.

7. Line speed should generally be between 12 and 15 mph. The exceptions will probably be on express or highway routes. Short round-trip times of 30 or 40 minutes should be avoided as the driver may not have enough margin to adjust his running speed or "make up time." In addition, 12 to 14 round-trips per day on the same route can be extremely monotonous for a driver.

8. All headways or frequencies should be divisible into an hour. In smaller transit systems most individual routes can be limited to one-hour round-trips. However, 1½- or 2-hour round-trips can and should be developed whenever possible to reduce the total number of routes.

9. In many smaller systems, timed transfers at a central point become necessary because of one hour and half hour headways. This means, in many cases, schedule times on segments of the

route are not coordinated to trip attractor times such as shopping, work and school. This type of time scheduling involves compromise. Individual routes should be developed specifically for heavily patronized areas so that more frequency in service can be justified.(1)

Combinations of or compromises of the guidelines will result in the system redesign. In order to implement a system redesign, the following considerations can make the transition easier for the passengers and the transit system operating personnel.

1. Resistance to change can be significantly reduced by attempting to utilize as many of the same bus stops as possible. This implies a compromise; if a bus stop or street is to be eliminated, there should be a definite advantage to the overall design.

2. Senior citizens are particularly sensitive to any routing changes. A bus stop can be moved one block and result in many complaints. The reason for the complaints is not generally because of an extra block walk; rather, a significant marketing/information effort was not made explaining the change and its reasons and benefits.

3. Bus drivers must understand and accept the changes, and then be trained sufficiently to operate at normal line speeds on the redesigned routes and schedules.(1)

Costs

The costs of redesigning a transit system are divided into the following components

1) planning the on-board survey

2) conducting the on-board survey

3) tabulating and presenting the data for analysis

4) analyzing the route and schedule design

5) redesigning the routes and schedules

6) implementing the redesigned system

7) operating the redesigned system

Since most transit systems have experience with on-board surveys, the planning costs should be low compared to those for the standard approach and focus on the changes needed to use this on-board survey approach. The costs associated with conducting the survey are basically the product of the hourly wage rate of the surveyors and the total number of vehicle hours surveyed. Data tabulation and analysis costs are dependent on the amount of data and the method of tabulation. The initial costs of developing and implementing computer software may be a substantial portion of the total cost. However, future tabulations will be less expensive. Both manual and computer tabulations will involve labor costs. The costs of analysis and redesigning are basically the wages of the analysis team members and are dependent on the amount of data analyzed and the number of problems to be addressed. Implementing the redesigned system includes the costs of planning detailed route and schedule operations, marketing/informing the public of changes, and performing the required procedures for service changes. Operating costs of the redesigned system are based on how the changes made relate to the original system. The major concern is with increases in operating costs due to additional vehicles, vehicle hours, or vehicle miles. Expected increases in revenue should also be considered.

Summary

This procedure for redesigning routes and schedules was developed as an interim method. It provides a good framework for system redesign and is very flexible. It can be expanded to make further use of the data collected to address the specific needs of a transit system.

This procedure was extensively demonstrated in a redesign of the Bellingham, Washington, Transit System for improved passenger efficiency and an adjustment of routes and schedules for passenger overloading at a California municipal transit service. It provides some innovative approaches to the use, analysis, and presentation of on-board survey data. The on-board survey is used not only for analysis but also for redesigning the transit system.

Methods for Service Design

Methods for service design identify problems in the existing system and design service changes for short-range transit planning (SRTP). SRTP is "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

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change."(2) The generic actions are listed by action level below.

1. Area coverage level--new route, route extension, a small set of routes replaced by a new set, route abandonment, shortening a route, route alignment, and change of service type or operator.

2. Route structure level--route splitting, zonal service, express or local service, linking of two routes, and deadheadings.

3. Frequency level--changes in route frequency.

4. Control level--installing or removing control points, changes in layover time or positioning time, and modifying running times.

SRTP is structured around four basic sequential planning activities: (1) problem identification, (2) design of alternatives, (3) analysis of alternatives, and (4) recommendation of the most promising alternative. The proposed SRTP is described below under four subsections: characteristics of transit operating agencies, problem identification, design of alternatives, and interfacing with other activities.

Characteristics of Transit Operating Agencies

Five characteristics of transit operating agencies are incorporated in the proposed SRTP as constraints or guidelines. The analysis and design must be based on data at the route and time period levels to reflect the multiple goals of the agency. The goals range from general goals such as providing mobility to the transportation disadvantaged to specific goals for a particular route or time period. The interdependencies between SRTP and related activities must be considered to ensure that the recommended actions will be acceptable to the total agency, and since the planning resources available are tightly constrained, it is important to focus on services that have high potential for payoff. A screening procedure is essential, since all possible alternatives and services can not be analyzed in detail.

The SRTP has to be able to respond effectively to changes in the operating situation of the agency, and, because of limitations in the state of the art of transit technical analysis, quantitative methods should be used to supplement, not replace, the planner's judgement and experience.

Problem Identification

The problem routes that must be identified, that is, routes whose performance could be significantly improved with the application of one of the generic actions, include substandard routes (problem-centered) and routes that could be improved in service efficiency but have no obvious problems (generic action-centered).

In the problem-centered approach, a small subset of all the generic actions are applicable for the specific problem. The type of problem and possible actions are identified by the most important performance indicator(s) as shown in Table 5.

The key to the generic action centered approach is the relationship between the potential to improve route performance by any generic action and a set of conditions on that route as shown in Table 6. It is noted that several types of performance measures may be required to measure the conditions. For example, points of low ridership can be indicated in a graphical load profile as in Figure 7; the potential for a route extension can be indicated by denoting areas of new development and traffic generators on a map; the potential for route extensions and splitting can be indicated by denoting possible bus turnaround points on a map; and verbal indicators -- comments from drivers, supervisors and planners -- could be used and later verified with data. The choice of performance measures depends on the cost, accuracy, and reliability of the data, and on the data currently available.

The problems associated with multiple objectives are addressed by ranking all the routes in terms of the performance measure selected for each goal. Since only similar services should be evaluated against each other, it is important to perform the ranking by corridor or area, or by time period. The rankings can be used as a screening mechanism to select routes for further analysis based on their ranking for one or more of the goals. Figure 8 demonstrates such a screening of passenger types. This type of ranking may result in a different ranking of route performance when compared to traditional ranking schemes based only on economic performance measures.

The problem identification step will result in a small set of routes that have the potential to be improved by one or more generic actions.

Table 5

Problems and Corresponding Actions

Problem	Measure	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

Source: Reference 2.

Table 6

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

Source: Reference 2.

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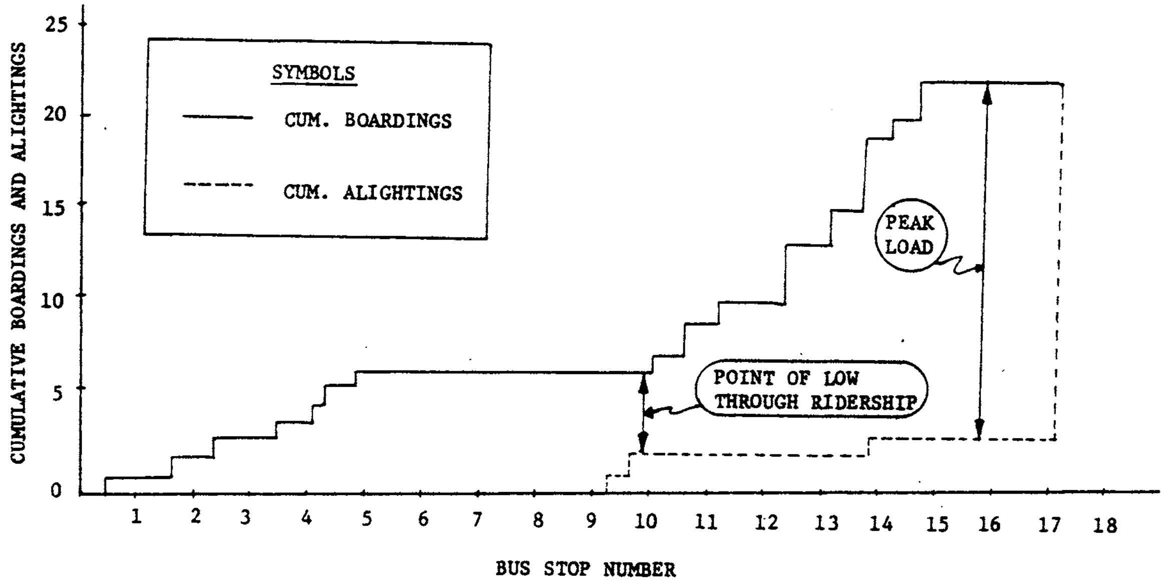

Figure 7. Plot of cumulative boardings and alightings for trip in a given direction. (From reference 2.)

ROUTE	DAILY SCHEDULED TRIPS	THE VARIABLES BELOW ARE, FOR EACH CATEGORY, THE AVERAGE PER TRIP AND THE RANK: REVENUE		TOTAL PASSENGERS		REGULAR		TRANSFER		STUDENT		ELDERLY		HANDICAP		CHILDREN		NO. OF CATEGORIES IN TOP 15%	NO. OF CATEGORIES IN BOTTOM 15%
		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

Figure 8. Multiple-objective ranking table for problem identification. (From reference 2.)

Design of Alternatives

The purpose of this step is to develop for these routes detailed alternative changes that can be evaluated for possible implementation. Information on the route segment level, such as ridership or running time, may be required. The use of adequate information is essential in this step. Consequently, formats for presenting ridership count data were developed using computer programs. Figure 7, a plot of cumulative boardings and alightings, is an example of this. In Figure 9, information by time period is provided for a specific passenger group. This is required for assessing the possible impacts of changes on a passenger group.

If the intent of the design step is to develop alternatives to better meet the overall objectives of the agency, then the agency should develop a set of alternatives or generic actions for each of its objectives. Consequently, preliminary design alternatives are available as a starting point and changes can be made quickly when necessary.

Interfacing SRTP with Other Activities

Scheduling, operations, marketing and community relations, and administrative activities are interrelated with planning, the most important relations being among operations, scheduling, and planning. For example, it is very important that the operational constraints be introduced into SRTP at an early stage to ensure that the alternative changes are practical. Determinations of the true expected cost of alternatives require close coordination between run cutting in scheduling and cost estimation in SRTP.

The best approaches for interfacing in SRTP depend on the capabilities of the transit agency. The steps in which other activities of the agency are important in the proposed SRTP are shown in Figure 10. The input of support function data with the decision tasks is also shown. Although not displayed on the figure, the development of alternatives and alternatives analysis are iterative processes to address concerns of the planners and to respond to input at interface points.

ALL THE STATISTICS PRESENTED BELOW ARE FOR TRANSFER PASSENGERS

TIME PERIOD	DIRECTION	DAYS SAMPLED	DAILY SCHEDULED TRIPS	EXPANDED TOTAL	PERCENT OF TOTAL	AVERAGE PER TRIP	90% CL LOWER BOUND	90% CL UPPER BOUND	BETWEEN DAY VARIANCE	BETWEEN DAY COEFF. OF VARIATION	WITHIN PERIOD VARIANCE	WITHIN PERIOD COEFF. OF VARIATION	90% CL ACCURAC
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

ALL THE STATISTICS PRESENTED BELOW ARE FOR ELDERLY PASSENGERS

TIME PERIOD	DIRECTION	DAYS SAMPLED	DAILY SCHEDULED TRIPS	EXPANDED TOTAL	PERCENT OF TOTAL	AVERAGE PER TRIP	90% CL LOWER BOUND	90% CL UPPER BOUND	BETWEEN DAY VARIANCE	BETWEEN DAY COEFF. OF VARIATION	WITHIN PERIOD VARIANCE	WITHIN PERIOD 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 9. Reports of transfer and elderly passengers for route 2. (From reference 2.)

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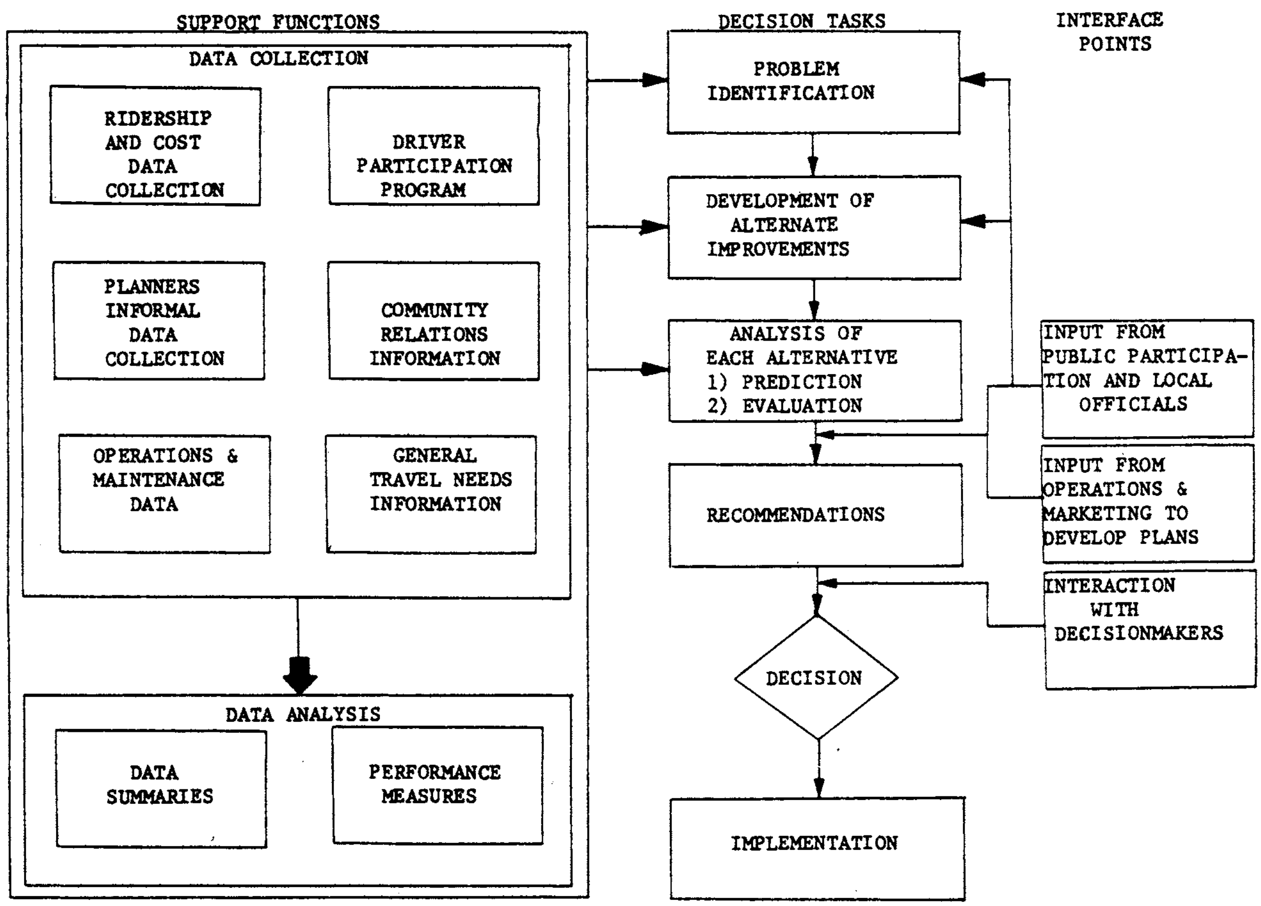


Figure 10. Proposed short-range transit planning process. (From reference 2.)

Costs

Assuming that substandard routes are already being addressed, the costs associated with implementing the proposed SRTP are as follows:

1) costs of investigating the routes that are not substandard but can be significantly improved

2) costs of presenting the data for analysis

3) costs of developing a strategy for addressing and ranking multiple objectives

The costs of investigating the routes that are not substandard should be offset by the improvements that are expected.

Summary

The most important change suggested in this proposed SRTP is to move away from an exclusive reliance on problem-centered screening by adding generic action-centered screening. The planner can employ alternative actions under the generic action-centered approach that are not feasible otherwise. The improvement of productivity on routes that are not substandard but have the potential for significant improvements with one or more generic actions may make resources available to effectively tackle the problem routes. Changes were also made (1) to consider the multiple objectives that transit operators strive to accomplish, and (2) to address the problem of formatting data in ways that are more directly useful in planning.

Timed Transfer Systems

Timed transfer is a coordinated network where several transit lines converge at a transit center or transfer point at the same time, thus enabling passengers to transfer between any two lines.(4) Timed transfers are being used to provide transit service in areas where transit demand is too low to support high levels of conventional transit service, to attract new riders, and to extend service into new areas. There are basically three types of timed transfer systems: simple timed transfer (2 routes at 1 transfer point), pulse scheduling (more than 2 routes at 1 transfer point), and multiple focal point timed transfer (more than 1 transfer point). Two variations of pulse scheduling are a line-up (pulse scheduling in the evening) and a neighborhood pulse (pulse scheduling for a subarea of the system). The various types of timed transfer can be used for transit systems of different sizes, subareas, or systemwide. Timed transfers are usually based on clocked headways; that is, where the scheduled routing times are the same every hour. Timed transfer appears to be applicable where there are (1) dispersed origin-destination patterns, (2) medium population densities (1,000 to 10,000 persons per square mile), (3) uniform demand density, and (4) headways greater than 15 minutes.(4,5)

Ridership increases of from 5% to 12% may be realized under some circumstances from the implementation of timed transfer.(6) Overall, timed transfer appears to be a cost-effective method of increasing ridership and service in many operating environments without necessarily increasing costs.

Some of the advantages of timed transfer are that (1) it is a system approach and services multiple destinations, (2) it is easy to understand because of regularity of service and transfers, (3) it gives flexibility in changing capacity without having to change schedules, (4) it integrates well with paratransit systems, and (5) it forces systems to analyze their network and schedules, bringing them into line with real demand.(17) Some disadvantages are that (1) traffic congestion may interfere with scheduled reliability, (2) discipline is required in transit operations to maintain reliability, (3) in general, there is a resistance to transfers by passengers, and (4) a massive overhaul of routes and schedules may be required.(17)

A procedure for planning and designing a timed transfer system, an evaluation of timed transfer systems, and case studies of timed transfer are described in the following sections.

Timed Transfer System Planning and Design Procedure

Vuchic et al. present a complete procedure for the planning of a timed transfer system (TTS) that emphasizes the basic relationships between routes that are necessary for TTS.(4) The TTS procedure is designed for an area with conventional transit services; however, using data based on projections, it may be applicable for areas without transit service. The procedure is divided into four stages: (1) initial planning, (2) analysis and preliminary planning, (3) final network planning, and (4) final operations planning (see Figure 11).

Initial Planning

The initial planning consists of three parts: decision to use TTS, definition of the service area, and collection of data. The decision to use TTS must be based on an analysis of the effectiveness of TTS compared to that of a conventional transit system. There are three conditions that favor the adoption of a TTS: (1) the travel demand in the area is characterized by dispersed origin-destination patterns, (2) the demand density is uniform and there are dispersed major trip generators with moderate concentrations at each one, and (3) the headways are greater than 15 minutes. If the analysis is positive, then the planning proceeds.

For an existing transit system, the service area is generally similar to the existing service area. Policy level of service standards relative to population or trip generation density should be adopted.

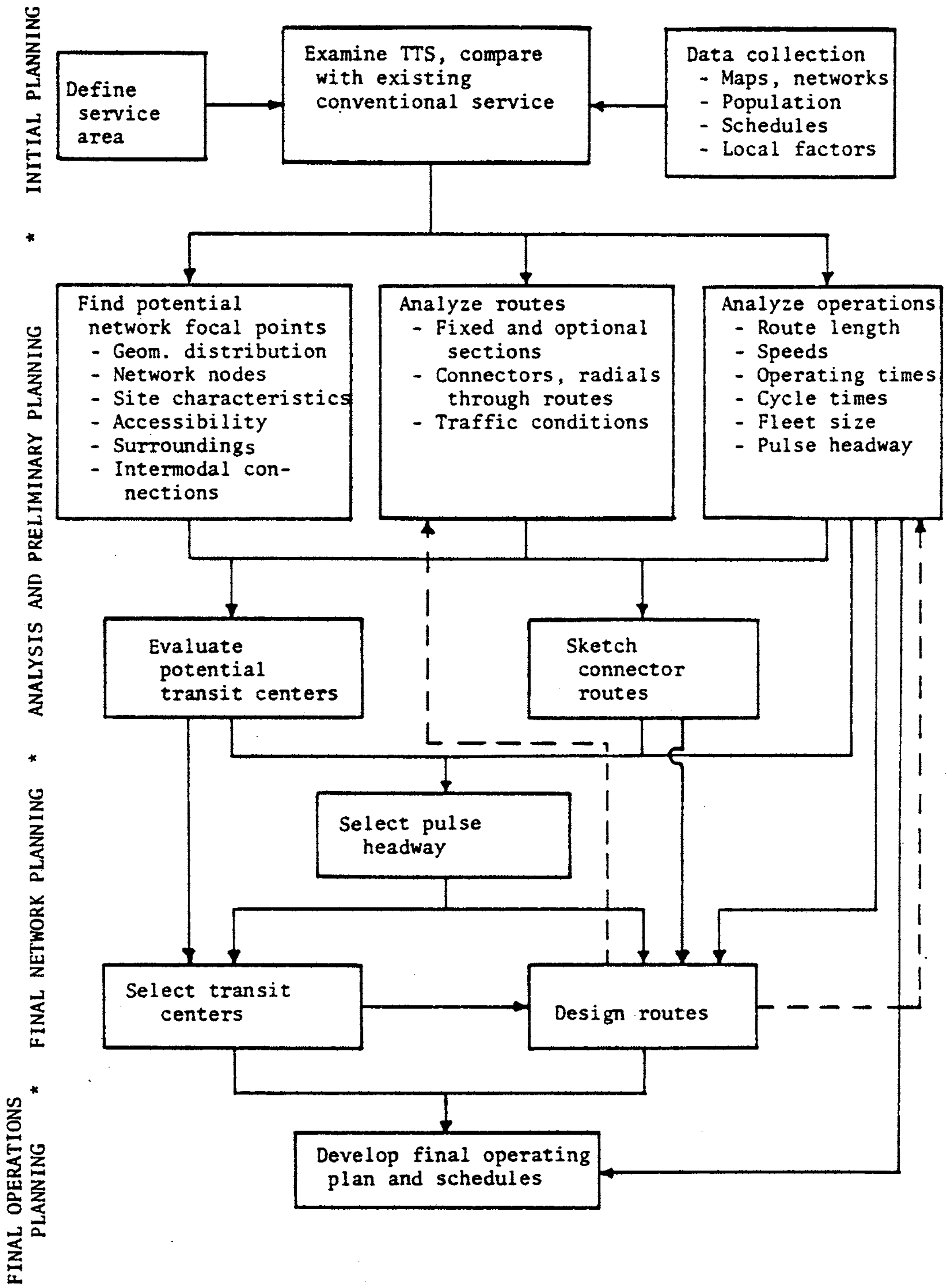


Figure 11. TTS planning procedure for an area with conventional transit services. (From reference 4.)

The general planning data and information that should be collected are often available from origin-destination studies performed by the local planning agency. For existing transit services, data on ridership (total and by route), trends in recent years, peak hour characteristics, transfers, reliability of services, operating elements of existing routes, and number and type of vehicles should be collected. Included are land use patterns, population size and density, major (present and planned) developments (such as shopping centers, residential or office complexes, factories, and recreational centers), street network, traffic conditions, and travel speed on streets at different times of the day.

Analysis and Preliminary Planning

The development of a preliminary sketch of the network indicating the overall pattern and orientation of the system considers potential locations for transit centers (network focal points), route alignments, and operations.

There are five major criteria for transit center locations as follows:

1. Transit centers should lie in certain geometric relationships among themselves, so that the TTS network can operate with joint headways.

2. Each location should be at an intersection of several transit routes, and preferably at a location with considerable demand.

3. Each location should have an adequate off-street area easily accessible by buses, but away from congested traffic arterials. In special cases on-street facilities may be used.

4. Transit center locations should be convenient for pedestrian and feeder mode access.

5. Transit centers should be "fitted" in the surroundings with respect to their design and character.

The locations that reasonably satisfy most of the criteria should be considered in further network planning. The basic types of TTS networks are (1) unifocal, (2) bifocal, (3) triangular, (4) linear multifocal, (5) rectangular multifocal, and (6) multifocal (general). These networks are illustrated in Figure 12. In general, bifocal and multifocal networks offer the following advantages over unifocal networks:

(1) expanded area coverage, (2) shorter travel time, (3) additional activity centers as focal points, and (4) a reduction in potential capacity and congestion problems at a single focal point. Their disadvantages are that (1) a significant portion of the overall travel time is transfer time, (2) there is a greater complexity of operations, and (3) there is an increased sensitivity to delay of each route on the network operations.

The route analysis and planning phase should identify the layout and characteristics of each route to be included in the TTS network. There are four categories of routes: (1) direct, which connect transit centers by alignments with the shortest travel times; (2) local, which connect transit centers and serve local areas along the way; (3) radial, which go from a transit center into the outlying service area; and (4) diametrical or through, which are radial routes that continue through the transit center in another radial direction. The fixed and optional sections of each route should be identified. A fixed section has a high transit demand level that requires scheduled transit, whereas an optional section is operated to increase area coverage and is not required in consideration of demand levels. If adjustments in route length are necessary, they should be made on the optional sections since such a change will result in relatively small impacts. An analysis should also be performed to assess the street and traffic conditions along each route. Ideally, each route should operate free of congestion and form the most direct link between two points. Operational factors such as one-way streets, adequate turning radius, and sufficient clearances should be considered. The final aspect of route analysis is to determine whether routes should be radial or diametrical through the transit center. An analysis is made to determine if route segments on different sides of the transit center have (a) similar demand characteristics so that both require the same headway, (b) many trips through the transit center, and (c) reliable service. If these conditions are met, then through or diametrical routes should be formed using the two routes.

The operations analysis incorporates operating elements, primarily headway, round-trip speed, cycle time, and number of vehicles, into the planning. The most important operational decision is the selection of the basic pulse headway, h_p, from the following two values of basic policy headways and their multiples:

a) 15 (and its multiples 30 and 60) minutes or

b) 20 (and its multiples 40 and 60) minutes.

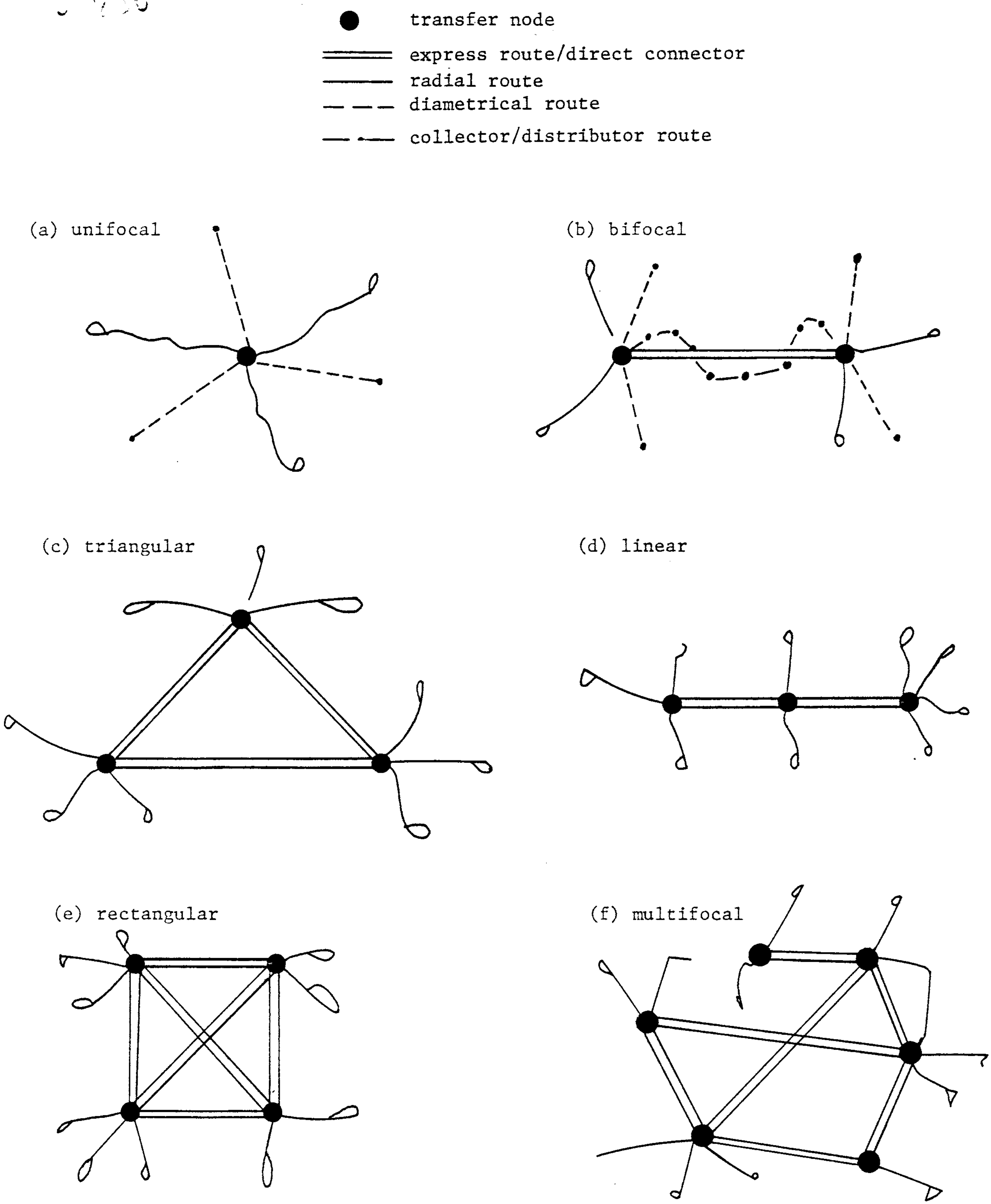


Figure 12. Types of TTS networks.

It is noted that a 40-minute headway is not evenly divisible into 1 hour and, therefore, is not a clocked headway. The basic pulse headway should represent the best compromise among all the routes. The headway that is closer to (preferably the same or slightly longer than) the ideal headway for each individual route should be selected as the route headway. The selected basic pulse headway determines the route length or travel time module between two terminals of a route. For direct routes, the distance between transit centers is determined. The relationship between route length, L, headway, h, round-trip speed, V, number of vehicles, N, and terminal (or waiting) times, T_t is

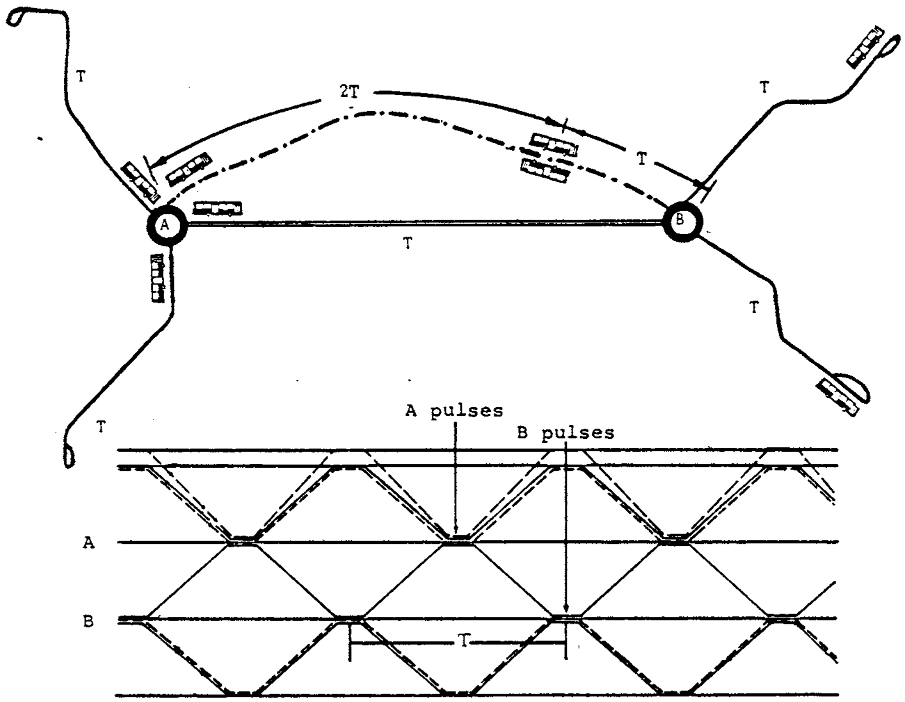
$$L = \frac{(h - T_t)}{2} \times V \times N. \qquad (1)$$

This equation can be transformed to determine the value of any one of the variables when the values of the others are known. After all of the route headways have been determined, the extent of synchronization of the timed transfers can be examined. If there is a single pulse in which all vehicles on all routes arrive and depart at the same time, then full synchronization (typical TTS) is present. If there are one or more pulses of groups of routes, then partial synchronization (a form of TTS) is present. Partial synchronization covers a wide range of transfer situations.

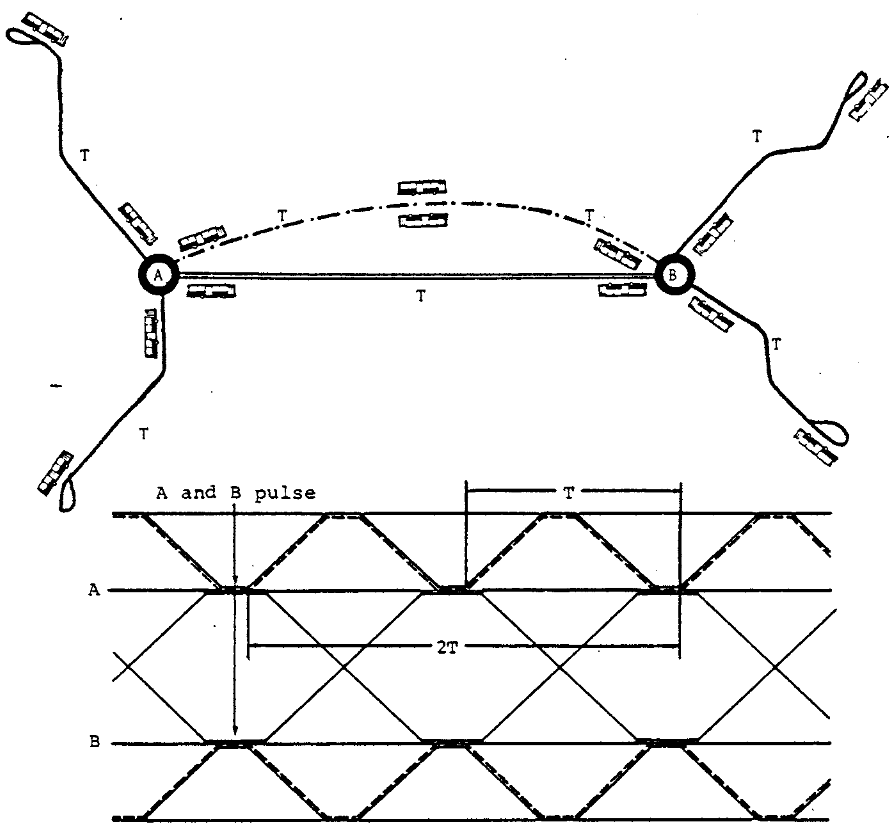
When two or more transit centers are connected by timed transfer, either a simultaneous or staggered pulse system occurs. A simultaneous pulse occurs when two or more transit centers in the network pulse at the same time. A staggered pulse occurs when the time of pulsing alternates between transit centers. These operations are demonstrated in Figure 13. Simultaneous pulse systems generally require more vehicles than do staggered pulse systems.

Final Network Planning

The analysis and preliminary planning stage determine the required route and operating elements in the network. Since an ideal fit of all of these elements is rare, adjustments must be made to fit individual routes into the required distance or time/speed module, or its multiples.



(a) Staggered pulsing between A and B focal points



(b) Simultaneous pulsing at A and B focal points

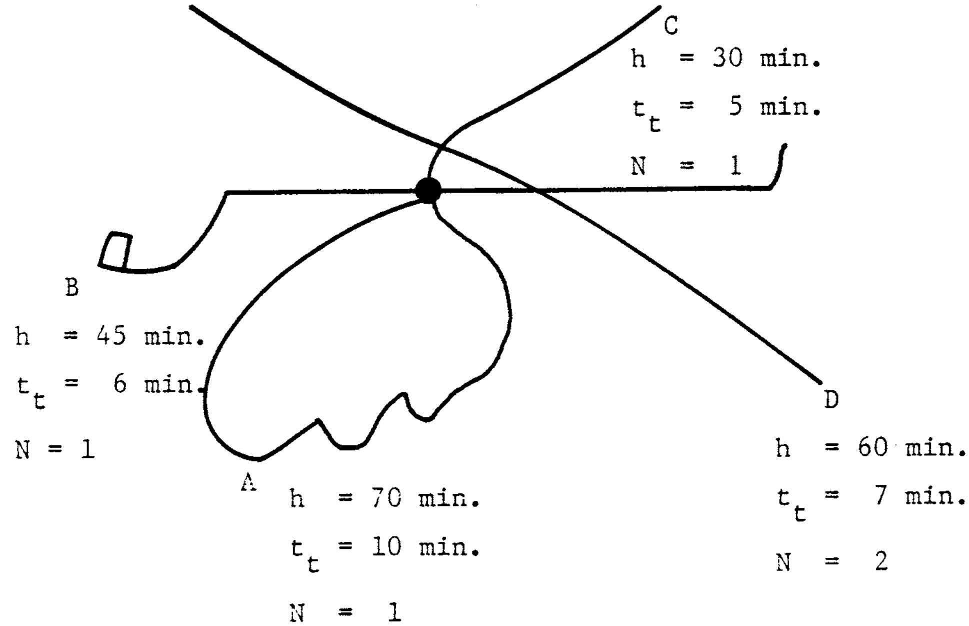
Figure 13. Staggered and simultaneous pulsing. (From reference 4.)

The primary methods of adjustment are (1) the addition or deletion of optimal sections of routes depending upon whether cycle time to that route must be lengthened or shortened, (2) the adjustment of terminal times to bring each route to the desired cycle time, and (3) a final selection of transit centers and the fitting of the network's operating elements.

The final operating plan and schedules for physical and operational elements of the entire TTS network are developed after the routes and transit centers have been determined.

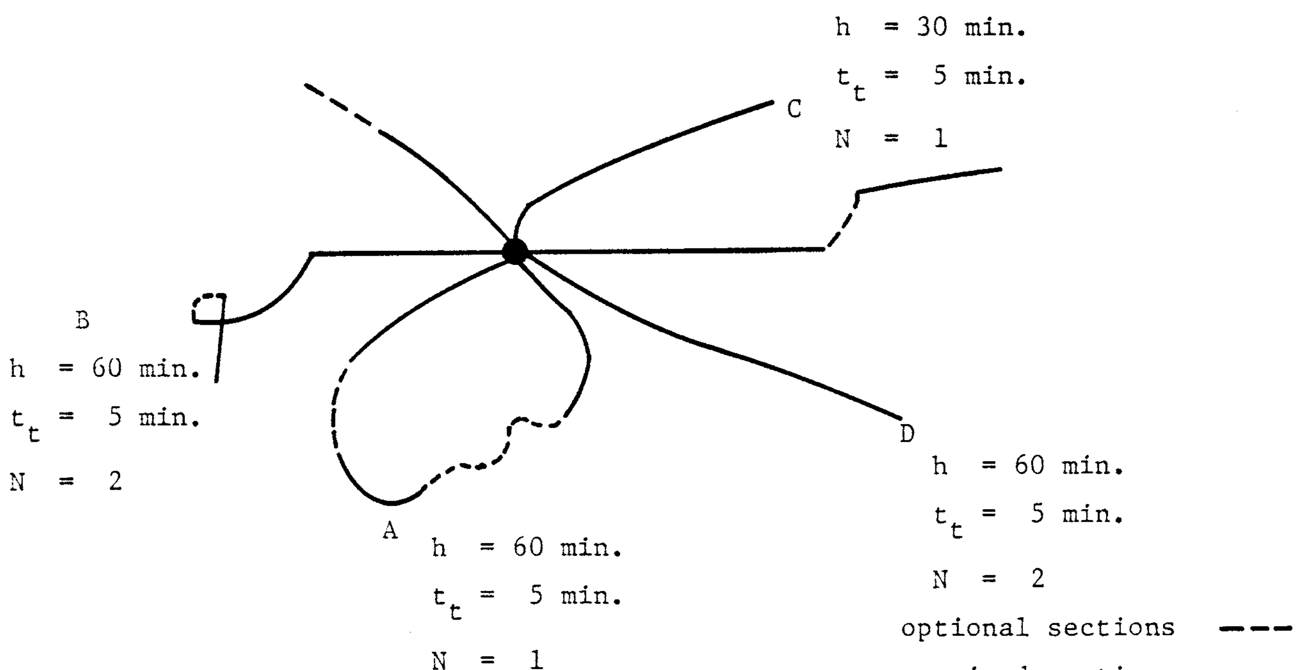
Example

A simplified example is given to illustrate the TTS planning and design procedure. Figure 14a displays an existing radial network of four routes. The results of the initial planning stage have indicated that a TTS network should be more effective than the existing one. The network focal point is the point where three of the existing routes intersect. Figure 14b displays a preliminary TTS network and the required and optional route sections. The result of the route analysis is shown in Figure 15. For the operations analysis, it is desirable that the headways of the TTS system be similar to the headways of the corresponding existing routes, viz., 30, 45, 60, and 70 minutes. A basic pulse headway of 60 minutes is selected as the best compromise among all routes. The route with a 45-minute headway may be extended and the route with a 70-minute headway may be reduced. In the final network planning stage, adjustments in the optimal route sections and terminal times are made (Figure 14).



Vo = 15 mph = .25 mpmin.

a. existing radial network



b. preliminary TTS network

Figure 14. Existing and preliminary TTS networks.

The final network planning calculations are as follows:

Transfer permutations (see Table 7) = $(N_c+2N_t)^2-(N_c-4N_t)=$

$$(2+2(2)^2-(2+4(2)) = 26.$$

Route length $L = \frac{h-T_t}{2} \cdot V_o \cdot N.$

For Route A, the existing $L = \left(\frac{70\text{ min.}-10\text{ min.}}{2}\right) \cdot 25\text{ mi./min.} \cdot 1\text{ veh.} =$

7.5 veh.-miles,

and

the proposed $L = \left(\frac{60\text{ min.}-5\text{ min.}}{2}\right) \cdot .25\text{ mi./min.} \cdot 1\text{ veh.} = 6.88$ miles.

Thus, the reduced length = existing L - proposed L = 0.63 veh.-miles.

For Route B, the existing $L = \left(\frac{45\text{ min.}-6\text{ min.}}{2}\right) \cdot .25\text{ mi./min.} \cdot$

2 veh. = 9.75 veh.-miles,

and

the proposed $L = \left(\frac{60\text{ min.}-5\text{ min.}}{2}\right) \cdot .25\text{ mi./min.} \cdot 2\text{ veh.} = 13.75$ veh.-miles.

Thus, the extended length = proposed L - existing L = 4.0 veh.-miles.

For Route C, there is no change.

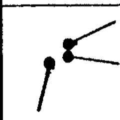
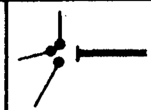
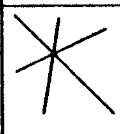
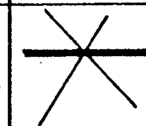
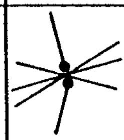
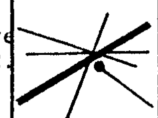
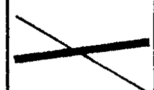
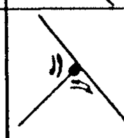
For Route D, the difference in route length = travel time increased by reduced

T_t of 2 min. = 2 min. x .25 mi./min. $\cdot$ 2 veh. = 1 veh.-mile.

The final network and degree of synchronization are shown in Figure 15. There is full synchronization on the hour. The example illustrates how a TTS may be planned and designed.

Table 7

Classification of Transfers by Types of Routes

Case number (1)	Number of lines: Terminating (2)	Number of lines: Through (3)	Transfer permutations (4)	Similar lines/routes: Sketch (5)	Similar lines/routes: Typical case (6)	Similar lines/routes: Comment (7)	Trunk with feeders: Sketch (8)	Trunk with feeders: Typical case (9)	Trunk with feeders: Comment (10)
1	N_e	0	$N_e(N_e - 1)$		Many suburban lines terminating	Coordination between lines needed. TTS can be applied successfully.		Trunk line terminating with many feeders	Requires coordination in case of transfers among feeders (TTS)
2	0	N_t	$4N_t(N_t - 1)$		Any point with several intersecting transit lanes	TTS desirable, but causes delay of through passengers		Trunk line station where feeders intersect	TTS possible. Feeders' arrivals and departures "around" trunk's stopping.
3	N_e	N_t	$(N_e + 2N_t)^2 - (N_e + 4N_t)$		Many transit lines terminate or pass through	TTS desirable; easier to achieve than with case 2.		Trunk line passes through where feeders intersect and/or terminate	
4	2	0	2		Terminal point of two suburban lines			Trunk line terminal with one feeder	
5	0	2	8		Intersecting point of any two transit lines			Trunk line station where a feeder intersects	
6	1	1	4		Point where one line terminates, another passes through			Trunk line passes through and feeder terminates	

Source: Reference 4.

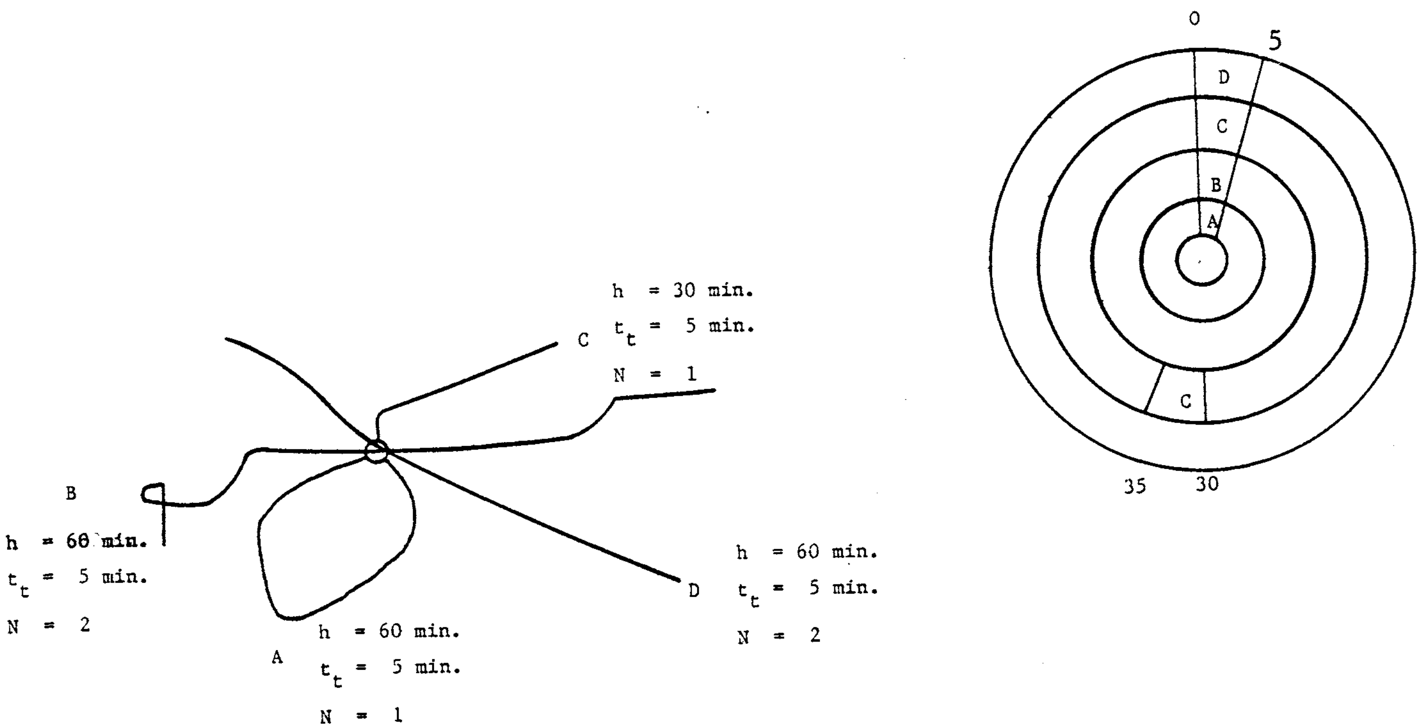


Figure 15. Final network design and synchronization.

Timed Transfer in Portland, Oregon

The Tri-Met Transit agency serving the Portland metropolitan area proposed to evolve toward a multicentered transit system using timed transfer service in an effort to serve areas in addition to downtown Portland. The first phase of this plan was implemented in the Westside area where radially-oriented service was inefficient. The internal Westside trips constituted 50% of all trips generated in the Westside, whereas Tri-Met carried 1% of the internal trips. Tri-Met carried 10% of the downtown trips, which were 8% of all trips. The schedule design was based on (1) clocked headways for local lines rather than passenger volumes, (2) off-peak running times as a basis for the design of local lines, and (3) consistent departure times throughout the day, seven days a week. It is noted that transit centers developed after the Westside transit centers are designed based on peak hour running times to give more flexibility in making any necessary changes. Timed transfer service at two transit stations in the Westside resulted in a 138.0%

increase in ridership for internal trips, a 15.0% increase for downtown work trips, and a 6.8% increase in downtown non-work trips in 1980 over 1977 levels.

Reliability was measured by two factors: a successful meet-all buses arriving as scheduled at a given time and a successful connection -- two routes arriving as scheduled resulting in a direct transfer connection. To overcome vehicle delay on the route run outbound from downtown, the schedules of the problem trunk routes and arrival/departure times of all buses were adjusted. The adjustments permitted the trunk routes to be up to 5 minutes late and still arrive in time to make all schedule connections. The trunk lines were scheduled to arrive 3 to 4 minutes before the locals, layover 3 minutes in the peak period (2 minutes in the off-peak period) and depart 3 minutes before the locals. Supervisors stationed at the transit centers ensured smooth meets by instructing drivers to hold the buses, answering questions, and relaying information to schedulers on consistently late buses. The supervisors, who also served as security officers, were not expected to be needed permanently but were important initially and during peak hours. Tri-Met also found that educating the drivers on the importance of making the timed meet contributed to the success of a meet.

Tri-Met has added three transit systems and plans to have ten transit centers by 1986. Two additional transit centers have been planned in conjunction with service reductions.(18) The objective is to implement timed transfer and reduce operating costs while improving service. The operating cost savings results primarily from a reduction in the number of vehicle trips to downtown Portland as a result of service by the feeder-trunk system.

Tri-Met is successfully using timed transfer to provide transit service to serve the new multidestination travel patterns.

Timed Transfer in Vancouver, Washington

The Vancouver transit agency, Citran, operates a bifocal TTS with simultaneous pulse operations every 30 minutes. The system, with a total of 23 routes, 18 serving the downtown transit center and 7 serving the Vancouver Mall center, is working well. All buses have a 5-minute wait at the transit centers. Two-way radios are used at a minimum, only for unusual difficulties. If a driver is more than 5 minutes late, it is his decision as to whether or not he will inform other drivers of the delay via the two-way radios.

Costs

The costs associated with the planning, design, and implementation of timed transfer are the following:

1) planning

2) designing

3) implementing

4) operating

The costs vary with the type of timed transfer, the number of routes involved, the size of the area, the extent of route and schedule changes. Implementation should include an information and marketing program.

Summary

The planning process is usually more complex than the diagram in Figure 11 indicates, because the sequences of steps is neither as discrete nor as regular as shown. The preliminary and final planning stages are performed nearly simultaneously in a complex iterative process. For transit systems in Virginia, basic policy headways of 30 and 60 minutes should also be considered to reflect current policy headways in small urban areas. It is sometimes beneficial to implement a multifocal TTS in incremental phases so that additional transit centers or focal points are included after experience is gained with the operation of a simpler network. The fundamental relationships between routes in TTS cited in this procedure are also described by Bakker(17).

Planning and Designing A Transit Center-Based Transit System: Guidelines and Examples from Case Studies in 22 Cities

The use of transit centers, interchange facilities that serve as a focal point for high levels of transit service, may provide efficient and effective transit service on an areawide basis. Schneider et al. developed guidelines for planning and designing transit centers.(8)

Planning and Designing a Transit Center-Based Transit System

The planning and design of a transit center-based transit system are conducted in five tasks: (1) selecting the number and locations of transit centers, (2) selecting subregional boundaries, (3) analyzing subregional travel patterns and market segmentation, (4) designing alternative route/schedule plans, and (5) implementing the design. These are discussed below.

Selecting the Number and Locations of Transit Centers

There are three locational objectives. First, transit centers should be well-distributed with respect to the region's population and employment distributions. Two indicators of this objective are (a) the local feeder bus round-trip time should be a minimum of 30 and maximum of 60 minutes, and (b) a useful guide for the population served by each center is a range of 25,000-100,000 persons. Second, transit centers should be located a reasonable distance from each other; that is, the minimum and maximum route distances should be 4 and 8 miles, respectively, assuming an average speed of 25 mph. Finally, transit centers should be located at well-known, easy-to-find locations.

A non-CBD transit center search should begin by identifying and mapping the region's major shopping centers (e.g., those with 30,000-1,000,000 sq. ft. of gross leasable area or with one (usually two) principal tenants with more than 150,000 sq. ft. of gross store area).

Selecting Subregional Boundaries

There are three ways to define subregional boundaries: (1) use shopping trade area boundaries (typically 4-5 mile radius or 15 minute driving time), (2) use circulation boundaries, or (3) use governmental jurisdiction boundaries. There are six criteria for adjusting the boundaries:

1) The entire transit service region should be enclosed.

2) The boundaries should conform as closely as possible to the areal limits associated with 30- to 60-minute bus travel times.

3) The natural and man-made barriers to travel should be recognized.

4) Each subregion should contain (in order of importance)

   a) substantial residential development (25,000-100,000 persons)

   b) a regional shopping center

   c) significant employment centers

   d) health facilities and services

   e) educational centers

   f) entertainment and recreational opportunities

5) The boundaries should not divide land use concentrations.

6) The boundaries should conform, when practical, to data collection zones, most importantly census tract boundaries.

These criteria must be ranked with respect to land use and transportation planning objectives.

Analyzing Subregional Travel Patterns and Market Segmentation

The three subregional travel patterns are: travel within subregions, travel between subregions, and travel from the subregion to the CBD. Market segmentation by these three should define the demand side of transit planning. The market segmentation should guide the rate and schedule design process, and attention should be given to the time characteristics of the travel patterns, i.e., peak and off-peak travel.

A profile of the socio-demographic and land use characteristics of each subregion should be developed. It should include, but not be limited to,

a) population counts, with sex and income breakdowns

b) population and employment densities

c) number of elderly and handicapped persons

d) growth potential in various parts of the subregion

e) employment locations and residential locations of employees

f) auto ownership and fleet mix characteristics

Designing Alternative Route/Schedule Plans

The three types of routes to consider are local, radial, and circumferential. The local route structure has three functions: (a) it serves as a feeder system from residences to the transit center, (b) it provides transit service within the subregion, and (c) it transports transferring riders from the transit center to destinations in the subregion. Line routes and narrow loop routes provide the best connectivity to a transfer point. During the peak period, frequent service should be provided. A balance between frequency and service coverage that minimizes the sum of walk plus wait times should be provided in the off peak.

Radial routes should provide high quality service with good bus speeds, preferably on freeways or major arterials. Radial routes should be developed by aggregating several existing CBD-bound radial routes.

Circumferential routes connect outlying transit centers and, as a secondary objective, provide peak period direct service from a transit center to outlying employment areas. For timed transfers, it is important that the buses on circumferential routes arrive at employment areas prior to those on local routes and depart soon after buses on local routes.

Alternative route and schedule plans should be devised and tested to assess performance. Public and special interest groups should be involved in the formulation and evaluation of alternatives.

Implementing the Design

A phased implementation strategy is highly recommended as opposed to a complete revision of the network all at once. It is suggested that the implementation process also serves as a market penetration strategy. Here, the major considerations are as follows:

1. Travel corridors to the CBD that are proposed to serve as radial routes should be identified and ranked according to volume.

2. Transit centers should be located and built in the highest volume corridors.

3. Existing radial routes should be aggregated into a single radial route according to the volume of traffic.

4. For each subregion, the local route structure should be converted to focus on the transit center. It is important to establish the basic network of local feeders first.

5. Next, the circumferential routes should be implemented.

6. The express service designed to connect the transit center directly with various regional employment centers should be implemented.

The monitoring of the implementation process is vitally important to ensure that expectations are realized. A fully developed transit center-based system is shown in Figure 16.

Transit Center Design Guidelines

The transit center design examines three areas: center design and layout, activity center circulation, and transit access to and circulation through the activity center area.

Transit Center Design and Layout

The transit center design and layout should optimize use of the available land. The sawtooth island designs are especially good where land values are very high because they minimize the amount of land required. Compared to other designs, sawtooth transit configurations allow buses a direct interface, reduce the walking distance between buses, and improve the visibility of the different buses to the rider. Sawtooth islands are useful for on-street (Figure 17) and off-street centers.

Activity Center Circulation

The transit center should be located to provide riders with direct, safe access to the various elements of the activity center. The first step is to identify major intra-activity center travel patterns.

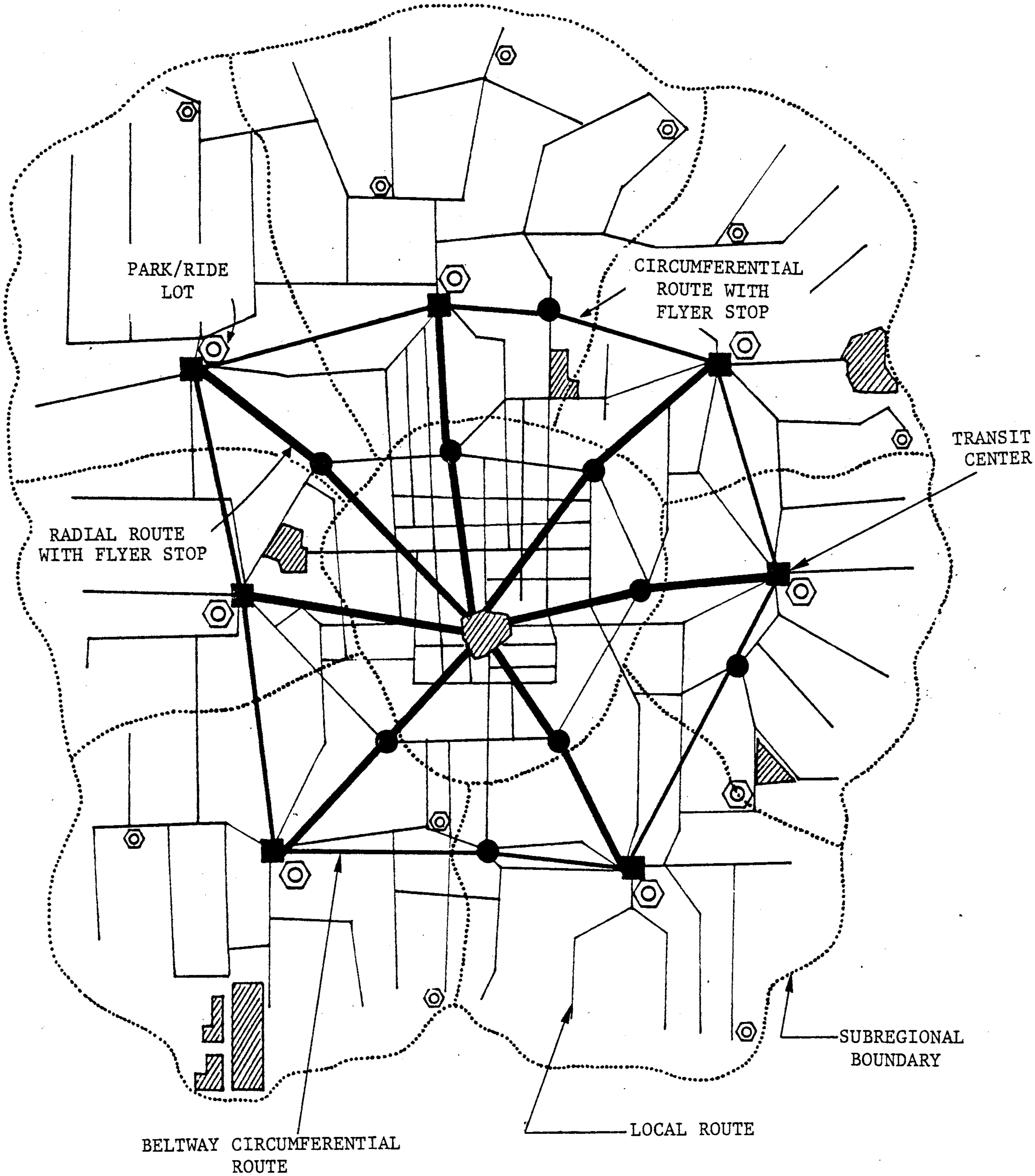
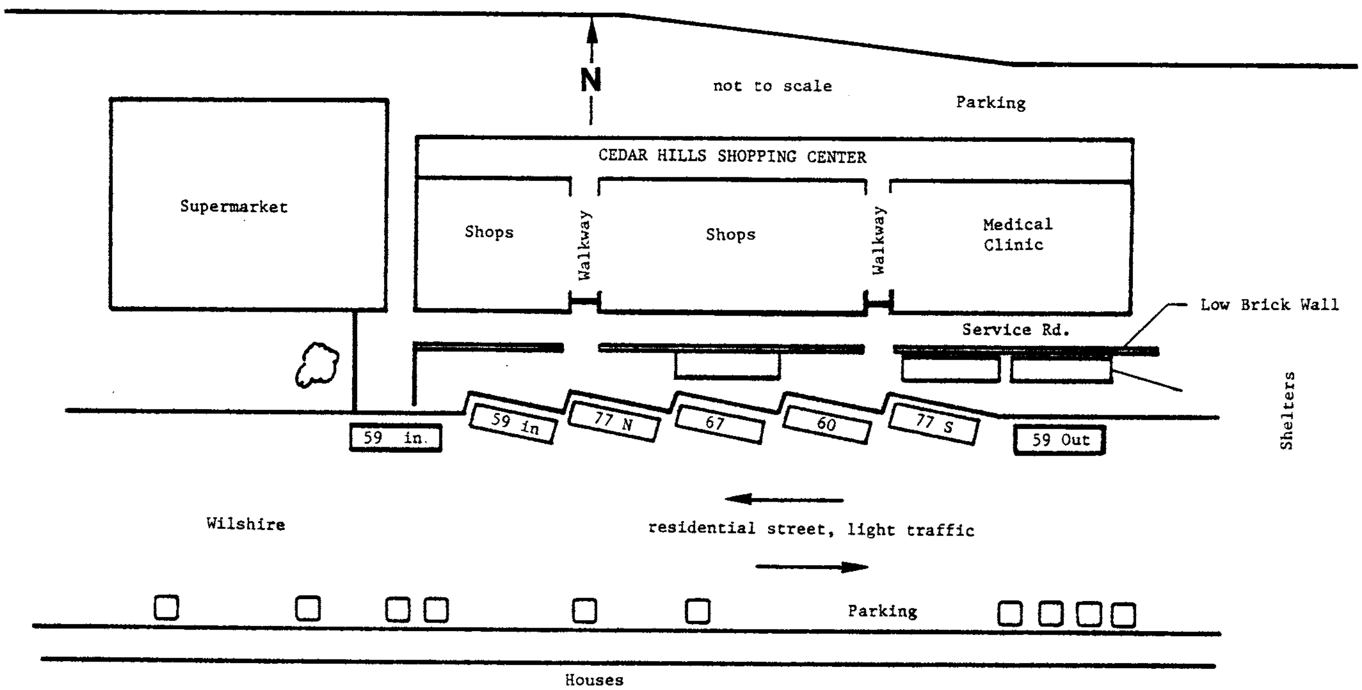
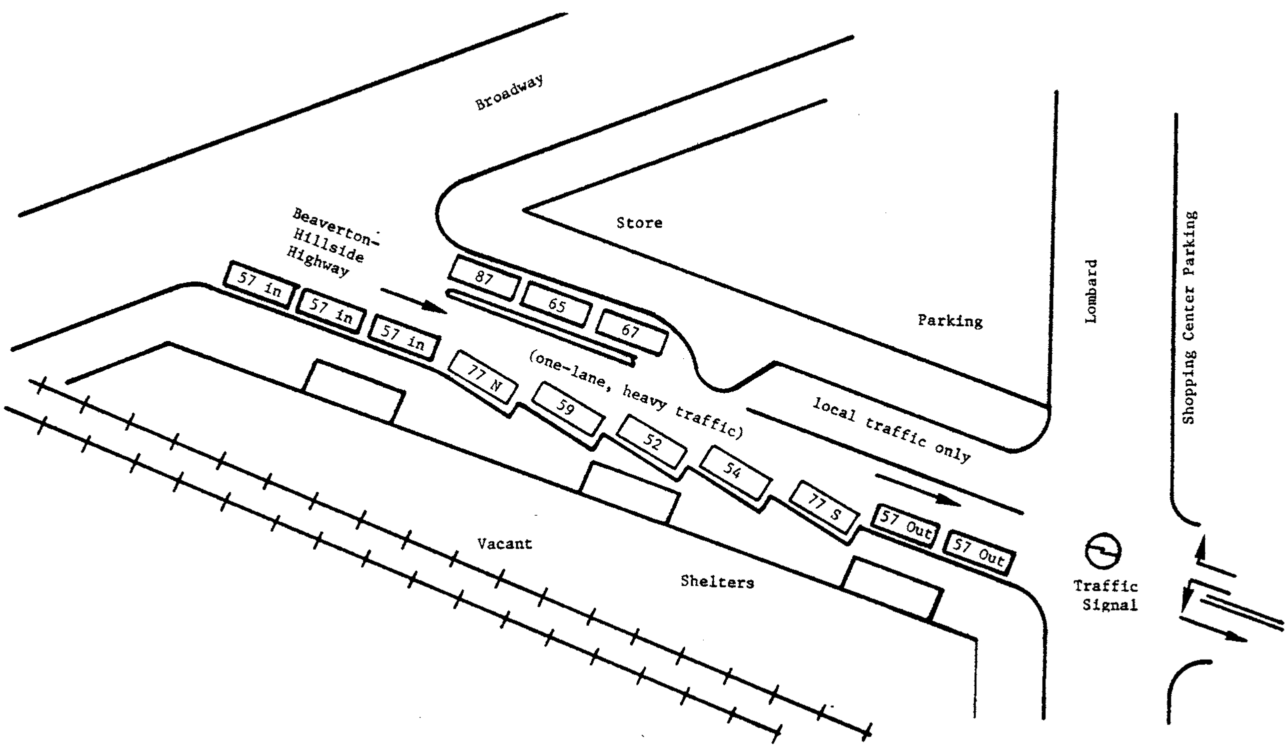


Figure 16. Fully developed center-based transit system. (After Schneider et al.)



a) Tri-Met's Cedar Hills Transit Center



b) Tri-Met's Beaverton Transit Center

Figure 17. Sawtooth transit bay configurations.
(From reference 18.)

Whenever possible, special pedestrian walkways such as sidewalks, bridges, tunnels, and moving beltways should link the transit center and components of the activity center. An automated circulatory system should be considered if the distance between the transit and activity center is greater than 1/4 mile or if that between the two most distant components of the activity center is greater than 1/2 mile.

Transit Access to and Circulation through the Activity Center Area

Routes serving the transit center should be designed to optimize transit access to the site and minimize travel time through the activity center. Transit center access can be maximized by (a) using transit only off-ramps to provide direct access, (b) using priority traffic management techniques, (c) locating the transit center for the easiest possible access, and (d) developing route patterns that minimize left turns against traffic.

Travel times through the transit center area can be minimized by (a) designing routes around the transit center area instead of through it (b) designing routes that have as few turns as possible in the transit center area, (c) designating the transit center as the only bus stop within the activity center, and (d) devising innovative loading and unloading practices.

Criteria for the Selection and Design of Transit Centers

The site selection and design criteria used in Eugene, Oregon, and Orange County, California, are shown in Figures 18, 19, and 20. The checklist of 36 criteria and measures developed in Eugene and a procedure for classifying transit centers in Orange County are provided. The following key locational criteria were used by Tri-Met Transit in Portland.(18)

1. adequate space for bus bays

2. proximity to major radial corridor

3. proximity to business and commercial areas

4. linkage to pedestrian walkways

5. site flexibility for future expansion

6) minimum walking distances between buses for transferring riders

7) minimum adverse impacts on traffic circulation

8) integration with the character of downtown

9) capital costs of construction

10) capital costs of right-of-way

11) opportunity for private sector participation through potential joint development

Costs

For a transit center-based transit system there are costs for planning, design, implementation, and operations. The planning and design costs are incurred in proceeding through the guidelines presented above and in developing detailed design plans. The major implementation costs are the cost of constructing the transit center, which could range from nothing to over $5 million. Also, information and marketing cost, and cost of making route and schedule changes are included. The operating cost may be increased or decreased depending on the goal of timed transfer (e.g., whether it is to add service or reduce service).

Summary

Transit centers serve as the focal point for timed transfer and feeder/trunk line systems. Twelve existing and ten planned transit centers were provided as case studies. The size and complexity and, consequently, the costs of implementing transit centers vary greatly. Transit centers are applicable for all transit systems and are especially important for timed transfer and trunk/feeder systems.

	CRITERION	MEASURE
1.	Distance from major downtown activity areas	Average distance from Eugene Mall, Government Center, planned performing arts center/convention hotel (ft.)
2.	Maximize coordination with intercity public transportation	Distance from AMTRAK and Greyhound-Trailways terminal (ft.)
3.	Proximity to retail/commercial employees	Number of retail/commercial employees within 2-block radius
4.	Proximity to government employees	Number of government employees within 2-block radius
5.	Proximity to retail floor space	Amount of retail floor space within 2-block radius (sq.ft.)
6.	Proximity to residential units	Number of residential units within 2-block radius
7.	Future employment growth nearby	Projected increase in employment within 2-block radius for each of 2 different scenarios
8.	Future growth in retail floor space nearby	Projected increase in retail floor space within 2-block radius for each of 2 different scenarios
9.	Future residential growth nearby	Projected increase in residential uints within 2-block radius for each of 2 different scenarios
10.	Use of contraflow lanes and signal preemption to expedite bus movement	Number of blocks of contraflow lanes
11.	Linkage to major pedestrian corridors	Subjective assessment of the length and quality of major pedestrian connections between transit transfer locations (for multisite alternatives; relative ranking)
12.	Linkage to major bikeway facilities	Subjective assessment (relative ranking)
13.	Mimimize bus miles in downtown area	Daily bus-miles in study area
14.	Average walking distance to employment locations	Employee-weighted average walking distance to each block within a 2-block radius at each transfer location (ft.)
15.	Opportunity for private sector participation through potential joint development	Subjective planning assessment of joint development potential (relative ranking)
16.	Provision of adequate bus bays to allow for layover points and for schedule coordination	Number of bays
17.	Site flexibility for future expansion for local transit or intercity carriers	Additional off-site area available (sq.ft.)
18.	Pedestrian space devoted exclusively to transit patron use	Additional on-street curb capacity (no. of bays) (sq.ft.)
19.	Distance between buses for transferring passengers	Average and maximum walking distance (ft.)
20.	Maximization of a sense of security and safety	Subjective assessment (relative ranking)
21.	Maximization of capability to be easily understood by the public	Subjective assessment (relative ranking)
22.	Maximization of visibility of transit center	Number of blocks of major pedestrian access from which the transit center could be made visible
23.	Maximization of the opportunity for imaginative, quality architectural design	Subjective assessment (relative ranking); number of important visual corridors and landmarks visible from each site (number of visual lines)
24.	Noise impacts on adjacent environments	Number of blocks with noise levels above HUD standards
25.	Air quality impacts on adjacent environments	Change in air quality
26.	Utilization of downtown land with potential development opportunities for transit use	Private land acquired for transit center site (sq.ft.)
27.	Proximity to adjacent uses	Length of business frontage within 200 ft. of transit activity area (ft.)
28.	Traffic impacts resulting from bus operations	Travel lanes effectively eliminated by transit center design or concentrated bus operations (ft.)
29.	Parking impacts	Number of spaces lost
30.	Energy conservation	Change in weekday bus-miles within study area (bus-miles per day)
31.	Retail disruption	Length of business frontage with less than 10-ft. buffer between transit activity and building fronts (ft.)
32.	Capital costs for construction	Estimated total construction cost
33.	Capital costs for right-of-way	Estimated site cost
34.	Annual operating and maintenance costs	Estimate includes annual bus-miles within study area and facility maintenance
35.	Fiscal impact of removing site from tax rolls	Loss of property tax revenues for a 10-year period
36.	Potential for funding availability from discretionary and demonstration monies	Estimated relative ranking

Figure 18. Criteria and measures used in transit center study in Eugene, Oregon. (From reference 8.)

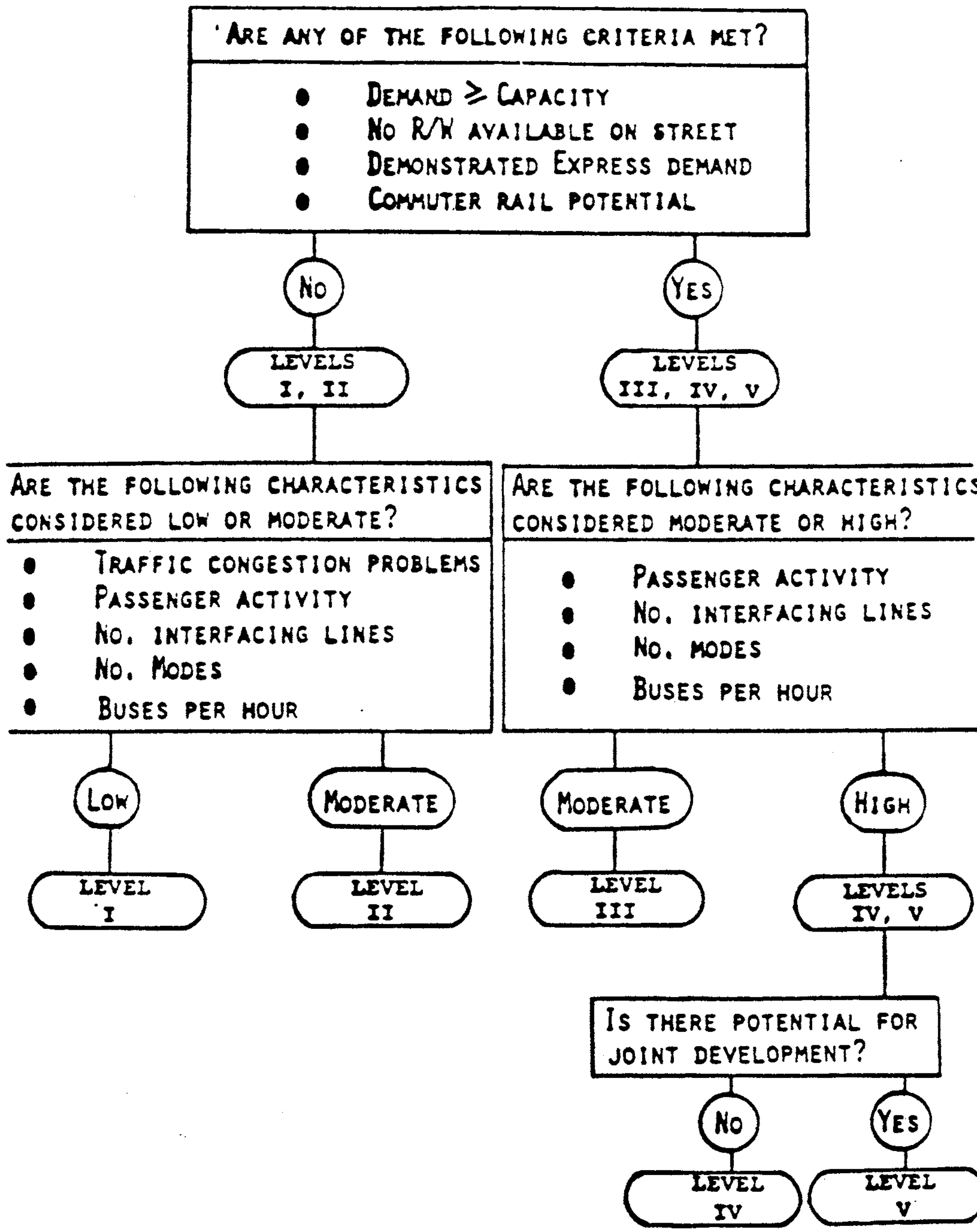


Figure 19. Transit center level evaluation process devised by Orange County Transit District. (From reference 8.)

QUANTIFIED CRITERIA FOR DETERMINING TRANSIT CENTER LEVEL

Category Description	Level V	Level IV	Level III	Level II	Level I
Bus bay demand/capacity	D>C	D>C	D>C	D<C	D<C
Potential for on-street expansion	No	No	No	Yes	N/A
Demonstrated demand for express service	Yes	Yes	Yes	No	No
Commuter rail interface	Yes	Yes	Yes	N/A	N/A
Traffic congestion - average daily traffic - service level	 >20,000 D, E or F*	 >20,000 D, E or F	 >20,000 D, E or F	 10,000-20,000 D, E or F	 <10,000 A, B or C
Passenger ons & offs (total daily)	>2,000	>2,000	1,000-1,999	500-999	100-499
Number of interfacing lines (total)	>12	>12	8-11	6-8	4-5
Number of modes served (total)	>6	>6	3-5	3-5	2
Buses per peak hour (total)	>25	>25	15-24	10-20	5-9
Recovery buses per hour (peak)	>5	>5	>5	0-4	0-4
Scale of activity center	Regional or major	Regional or major	Major or community	Community	Community
Commercial use of facility	Yes	No	No	No	No

*A, B, C, D, E, F: represent the levels of traffic congestion according to the Highway Capacity Manual of 1965. Level A depicts an ideal full-flow condition; Level F depicts worst forced flow condition, etc.

N/A: not applicable

PASSENGER AMENITIES ASSOCIATED WITH EACH TRANSIT CENTER LEVEL

Facility Amenities	Level V	Level IV	Level III	Level II	Level I
Benches	X	X	X	X	X
Information signs	X	X	X	X	X
Shelters	-	-	X	X	X
Enclosed or semi-enclosed structures	X	X	-	-	-
Concrete bus pads	X	X	X	X	X
Public telephones	X	X	0	0	0
Recovery (layover) area	X	X	0	0	0
Restrooms	X	X	0	-	-
Landscaping	X	X	X	0	-
Ticket and information booth	0	0	-	-	-
Bicycle racks	0	0	0	0	0
Lighting	X	X	X	0	0
Vending machines	0	0	0	-	-
Private carrier accommodations	0	0	0	0	-
Public parking	0	0	0	-	-
Commercial/office space	0	-	-	-	-

X = essential
0 = optional
- = unnecessary

Figure 20. Criteria used to define characteristics of transit centers in Orange County, California. (From reference 8.)

Transit Operator Guidelines for Transfer Policy Design

A transfer policy is "a set of operator actions involving vehicle routing and scheduling, transfer charges, information for passengers, and terminal facilities which affects the movement of passengers between transit vehicles (bus and/or rail) as part of a continuing trip."(7) The guidelines aid the transit operator in selecting a transfer policy that best meets local goals and objectives. The transit operator may use the guidelines to determine the policies that may be beneficial to his system and to identify policies that may produce particular types of effects.

Of the seven policies presented, two routing and two scheduling transfer policy options that affect current transfer practices are discussed below. One of the scheduling options, timed transfer, has already been discussed. Two other scheduling components, schedule adherence and service frequency on connecting routes, are not discussed because non-transfer-related factors are more important in determining their application.

Distance Between Routes at Transfer Points

The walk required between vehicles when transferring is a basic attribute of transferring. The greater the distance between routes, the lower the utility for the transfer. Ideally, the transfer walk distance is less than 1 or 2 blocks. "The reduction of transfer walk time will have a greater effect on user satisfaction than an equal reduction of transfer wait time as in-vehicle line haul time."(7) Therefore, a reduction in the transfer walk where routes are widely separated may yield a substantial increase in transferring and a small, significant increase in overall ridership. The principal costs associated with transfer walk reductions are changes in vehicle miles and vehicle hours of operation. Two major constraints determine how closely a given transfer point can approach the ideal situation. First, the maximum number of buses that can be present simultaneously in the area of a single bus stop is approximately 20, and second, the desired transfer walk distance between all vehicles at a single transfer point is obtainable only when the CBD is small enough so that the transfer point is within walking distance of all of the CBD.

There are six types of transfer walk distance practices as described below.

1. Baseline alternative -- Vehicles are routed on the basis of operational and non-transferring demand considerations only.

2. Central on-street transfer area -- The termination points of all routes are within 1 or 2 blocks of each other when physically feasible.

3. Off-street transfer facility -- The transfer walk distance and pedestrian obstacles are reduced by removing buses and transfer passengers from the street. The number of buses that can meet at one point increases. It may require the use of a noncentral location and significant capital costs. Therefore, this option is best implemented when there are non-transfer-related benefits such as a reduction in street congestion.

4. Bus transit mall -- All or nearly all of the bus routes entering the CBD travel a designated street so that all routes pass the same points. This option is most feasible when the CBD is narrow (e.g., 4 blocks) and implementation can occur without significant capital costs.

5. Subfoci -- Routes with large numbers of transfers among them are grouped and terminate at the same spots. Routes serving the same geographical area may be clustered and a transfer point placed on the opposite side of the CBD. The CBD is well covered, the overall number of routes is not a constraint, and transfers between routes at subfoci are easy. The use of subfoci results in increased operating costs due to additional vehicle miles in the congested CBD, thereby restricting their use in larger cities.

6. Grid network -- Vehicles are routed in a grid pattern that produces intersections between many or all nonparallel routes. Grid networks are most often employed in cities with large central areas of high density employment and population. The distances between routes at transfer points are minimized. Dispersed transfer points may be less desirable and less safe in the evening than single points or subfoci.

Through-Routing

Through-routing, or "interlining," is the linking of two routes so that the same vehicle travels on both. There are two reasons for the use of through-routing: to reduce operating costs and to accommodate riders. Through-routing for operations can produce significant cost savings by eliminating turnaround time and distance, improving opportunities for logical scheduling, and providing potential gains in service reliability. The net effect of through-routing is generally a cost reduction, although headway matching may increase cost and extra scheduling effort may be needed. The use of through-routing in cities with a congested CBD where routes enter from more than one direction is most likely to result in substantial cost savings. As an aid to logical scheduling, through-routing is most applicable when transit properties are constrained by service area boundaries or when operators seek to maintain clock face or pulse scheduling. The operational and cost consequences of through-routing depend heavily on the street layout and other conditions, such as the elimination of dangerous left turns.

Through-routing for ridership eliminates waiting and walking times and produces significant benefit for riders through the elimination of transfers. Through-routing for ridership is often profitably employed where there is a high volume of transferring passengers between two routes with a common terminus.

These two reasons for through-routing are not necessarily incompatible. However, route pairings that maximize cost and operations benefits may not maximize user satisfaction.

The advantages and disadvantages of publicizing routes differ for the two objectives. When connections for through-routing for operations are not publicized, future changes in route pairings are easier to make than would otherwise be the case. On the other hand, ridership benefits will be minor in the short run. User satisfaction may be increased by publicizing through-routing; however, this publicity will tend to restrict future adjustments in route pairs because they might create low user satisfaction and public relations problems.

The five types of through-routing currently in use are discussed below.

1. Classic through-routing -- Two separately identified routes with the same headways and terminal points share the same vehicles. The terminal points are usually in the CBD but may be at an outlying terminus. The pairing of routes may be publicized on the schedules.

2. Single through-routing -- This differs from classic through routing only in that the two route halves are formally identified as a single route on a permanent basis.

3. Variable through-routing -- Buses are exchanged among many routes over the course of the day rather than just between two route pairs as in classic through-routing. Extensive scheduling is needed, but matching headways are not. This type is beneficial where there is a relatively dispersed flow of transferring passengers and for riders (e.g. the elderly) that can afford to wait for a particular time of day for service.

4. Trippers -- Trippers are buses that are through-routed at particular times of the day, usually to serve peak demands or to meet work shift or school times. Extra buses must be added or normal runs of regular routes must be extended. Trippers are applicable where there are periodic peak flows to particular points.

5. Overlap -- A radial route is terminated on the opposite side of the CBD from which it entered to eliminate some distributor/feeder transfers downtown. This may result in extended route lengths. Overlap is applicable where there is a large amount of transferring to reach destinations within the CBD.

Schedule Coordination

Schedule coordination is the adjusting of schedules on routes to change the offset between times of arrival of the vehicles at transfer points for the purpose of reducing average waiting times. Typically, one bus is scheduled to arrive before another bus. "If transfers are strongly directional between 2 lines at any time of day, and if a reasonable degree of schedule reliability exists, schedule coordination may be a very productive action...."(7) Typically, the costs are small, only minor headway changes are needed, and no real-time operator attention is required.

There are two constraints on the application of schedule coordination. The major one is the need for strong directionality of transfers. Schedule coordination can be used in the CBD only when there is a skewed distribution of origins and destinations by time of day. Since this condition is more likely to occur in smaller cities than larger ones, city size is a constraint on the applicability of schedule coordination.

The following three forms of schedule coordination are currently being used.

1. CBD schedule condition -- This is used when there is a strong directional flow of transfers from one area of the city to another through the CBD during peak hours. Overall ridership and revenue gains of from 3% to 4% are reasonable. Although it requires some scheduling effort and headway changes sometimes, this option can improve the level of service of transferring passengers.

2. Trunk-crosstown coordination -- Under this option, the evening peak schedules of low frequency crosstown buses are adjusted so that they arrive just after trunk line buses. Because of the high frequency trunk service, this scheme benefits passengers transferring from trunk to crosstown without seriously inconveniencing passengers transferring in the other direction. Overall ridership and revenue increases of about 2% are expected from this low cost option. Trunk-crosstown coordination is more widely applicable than CBD schedule coordination because it is less sensitive to the directionality of flow.

3. Minor schedule coordination -- This type of coordination is typically implemented in response to passenger complaints on their inability to make connections between two specific routes. The schedule of the particular run on the connecting route is adjusted to ensure that a transfer can be made. This option can be easily implemented at a very small cost on any transit system at any time of day. It typically does not result in ridership gains.

Dynamic Control of Departure Times at Transfer Points

Dynamic control is holding a bus past its scheduled departure time from a transfer point to allow a transfer connection with a vehicle approaching the transfer point. Information is conveyed by radio or some other signaling device such as headlights. Typically, the maximum holding time is 5 minutes; however, longer times are possible when a premium is placed on guaranteeing transfers (e.g., during late evening service). Dynamic control is most frequently used in conjunction with schedule coordination or timed transfer.

The major constraints on the use of dynamic control are the size and complexity of the system, since large, complex networks may experience harmful schedule disruptions. Dynamic control is applicable where it is beneficial to guarantee transfers between two low frequency routes and where a low frequency route receives a significant number of passengers from a higher frequency route.

When used alone, dynamic control is appropriate when transfer flows are intermittent or when schedule unreliability is common. It may be an acceptable compromise for operating costs and user satisfaction between no reduction in schedule uncertainty and the addition of layover time to absorb all schedule variance.

Its use is not widespread.

Costs

The costs for transfer policies vary with the transit conditions, number of routes, changes in vehicle miles, vehicle hours, and the extent of implementation of a policy.

Summary

The transfer policy components or options presented are important and deserve consideration when a transfer policy is being examined. All of the transfer policy options are currently used on transit systems.

Recommendations for Implementation

Recommendations for implementing the five innovative concepts described in detail above are presented by (1) the functions and applicability of the concepts, (2) problems experienced by transit systems in Virginia, and (3) transit systems in Virginia. Although there is overlap among the three approaches, all are beneficial. In the concept-centered approach, conditions under which the concept may be applicable and beneficial are defined. For the problem-centered approach, innovative concepts that can solve the problem are identified. Finally, the conditions of a particular transit system make it possible to suggest innovative concepts for consideration. The recommendations for particular transit systems are based on the limited information obtained in the survey and in interviews with personnel of three systems.

Functions and Applicability of Innovative Concepts

An overview of the functions and applicability of the innovative concepts is shown in Table 8. A transit planner or operator is able to select one or more of the innovative concepts that are appropriate to his needs.

Table 8

Functions and Applicabilities of Innovative Concepts

1. Redesigning Transit Systems

   -- is applicable and recommended for all systems, especially small and medium-size transit systems (1-6 buses per hour per route)
   -- collects data using an on-board survey and makes much greater use of on-board survey data compared to current usage
   -- is especially helpful for transit service expansions or reductions
   -- is beneficial for all redesign considerations
   -- includes a passenger overload analysis

2. Methods for Service Design

   -- are applicable and recommended for all systems' short-range transit planning
   -- include routes that are not substandard but can be significantly improved (generic-centered)
   -- list possible actions for problem-oriented and generic-centered routes
   -- address multiple goals and objectives in the screening of route performance
   -- provide useful data formats

3. Timed Transfer System

   -- is applicable and recommended, to some extent, for all systems where there are dispersed origin-destination patterns, medium density (1,000 to 10,000 persons per square mile), uniform demand density, and headways greater than 15 minutes
   -- provides an approach to plan and design a timed transfer system
   -- can be used to modify or examine an existing timed transfer system
   -- is useful as a tool for identifying and solving routing and scheduling related problems for a timed transfer system

4. Planning and Designing Transit Center-Based Transit Centers

   -- is applicable for all systems
   -- is especially useful and recommended for use in coordination with timed transfer, trunk/feeder systems, etc.
   -- provides a step-by-step procedure for planning and designing transit centers

Table 8 (continued)

5. Transit Operator Guidelines for Transfer Policy Design

    -- is applicable for all systems
    -- is useful and recommended for investigating or changing transfer policy

Routing and Scheduling Problems and Applicable Innovative Concepts

In Table 9, the routing and scheduling problems that were identified in the survey and applicable innovative concepts that can resolve the problems in general are listed. Additionally, the transit systems in Virginia that are experiencing a particular problem and a recommended concept for consideration in solving the problem are presented. It is noted that there is a natural tendency for overlapping routes to exist near transit focal points such as the CBD, and this is not necessarily a problem. Although not listed on the table, trunk/ feeder systems may be applicable for overlapping routes.

Transit Systems in Virginia and Innovative Concepts Recommended for Consideration

Innovative concepts that are recommended for consideration by each of 15 transit systems in Virginia are listed in Table 10. The recommendations are based on the operating environments of the transit systems and the problems they are experiencing. As noted in Table 7, all of the innovative concepts are applicable for most transit systems. Consequently, more than one innovative concept are recommended for consideration by several of the transit systems. The procedure for redesigning transit systems is recommended for all of the small urban transit systems. Timed transfer and transit centers are recommended for all of the small urban centers without timed transfer. Since the route structures of the systems are radial, timed transfer at the CBD has the potential to improve service efficiency and effectiveness with minor to moderate changes in routes and schedules. Redesigning transit systems can be used to collect and analyze on-board survey data, and timed transfer can be considered a preferred alternative for transit systems where both concepts are recommended. Since timed transfer is a form of a transit center-based transit system, the transit center-based transit center guidelines can be used to supplement timed transfer as well as being used separately with other transfer policies. Methods for service design are recommended for the larger transit systems. Transfer policy guidelines and/or timed transfer are recommended for transit systems that have noted uncoordinated transfers as a problem. Other recommendations are related to specific problems.

Table 9

Routing and Scheduling Problems and Applicable Innovative Concepts

Problems	Concepts and Transit Systems
1. overlapping routes	general--Redesigning Transit Systems
	Winchester City Transit--redesigning transit systems; timed transfer
	Charlottesville Transit--redesigning transit systems
	Greater Richmond Transit--redesigning transit systems
	Pen Tran--redesigning transit systems
	TRT--redesigning transit systems
2. need to change headways	general--methods for service design; redesigning transit systems; timed transfer for timed transfer systems
	James City County Transit--redesigning transit systems
	TRT--methods for service design
	WMATA--methods for service design

Table 9 (continued)

3.	uncoordinated transfers	general--transfer policy guidelines
		Pen Tran--transfer policy guidelines
		TRT--transfer policy guidelines
		WMATA--transfer policy guidelines
4.	need to extend routes	general--redesigning transit systems
		Blacksburg--redesigning transit systems
		WMATA--redesigning transit systems
5.	need to truncate routes	general--redesigning transit systems; methods for service design
		James City County--redesigning transit systems
		WMATA--methods for service design
6.	need to add new routes	general--redesigning transit systems
		Charlottesville Transit--redesigning transit systems
7.	slow speeds	general--redesigning transit systems; methods for service design
		Charlottesville Transit--redesigning transit systems
		WMATA--methods for service design

Table 9 (continued)

8. overcrowding	general--redesigning transit systems: passenger overload analysis; methods for service design
	Harrisonburg City Bus Service--passenger overload analysis
	Blacksburg Transit--passenger overload analysis
9. excessive deadheading	general--redesigning transit systems; methods for service design
	TRT--methods for service design
10. service unreliability	general--redesigning transit systems; methods for service design
	TRT--methods for service design
11. multiple branches on route	general--redesigning transit systems; neighborhood pulse (a form of timed transfer)
	Greater Richmond Transit--neighborhood pulse; redesigning transit systems
12. delays due to congestion, railroad crossings, draw bridges	general--redesigning transit systems
	TRT--redesigning transit systems

Table 10

Transit Systems in Virginia and Innovative Concepts
Recommended for Consideration

Transit System	Applicable Innovative Concepts
<u>Timed transfer based radial</u>	
Harrisonburg City Bus Service	Redesigning transit systems including passenger overload analysis
Winchester City Transit	Redesigning transit systems
Staunton Transit Service	Redesigning transit systems
Blacksburg Transit	Redesigning transit systems including passenger overload analysis
Petersburg Area Transit Service	Redesigning transit systems
<u>Small Urban Radial</u>	
James City County Transit	Redesigning transit systems
Charlottesville Transit Service	Redesigning transit systems; timed transfer; and transit center-based systems
Danville Bus Service	Redesigning transit systems; timed transfer; and transit center-based systems
Bristol City Bus System	Redesigning transit systems; timed transfer; and transit center-based systems
Greater Lynchburg Transit Company	Redesigning transit systems; timed transfer; and transit center-based systems
Greater Roanoke Transit Company	Redesigning transit systems; timed transfer; and transit center-based systems
<u>Medium-size Urban Radial</u>	
Greater Richmond Transit Company	Methods for service design; neighborhood pulse for multiple branches
<u>Multifocal</u>	
Peninsula Transportation District	Methods for service design; transfer policy guidelines and/or timed transfer
Tidewater Transportation District	Methods for service design; transfer policy guidelines and/or timed transfer
Washington Metropolitan Area Transit Authority	Methods for service design; transfer policy guidelines

All of the transit operators may wish to consider the procedure for redesigning transit systems and methods for service design, because the benefits resulting from the concepts (see Table 7) are not dependent on the system size. These two concepts emphasize procedures in planning and design of routes and schedules rather than a specific routing and scheduling strategy.

The recommendations for consideration of innovative concepts are based on an overview of the routing and scheduling conditions, problems, and needs of a specific transit system and its service goals, objectives, and transfer policies and practices. The list in Table 9 is a starting point for the respective transit operators. They can contemplate the recommended concepts, then select the ones that they wish to consider for detailed planning, design, and implementation.

Costs for Planning, Implementing, and Operating the Innovative Concepts

It is difficult to discuss the costs for planning, implementing, and operating the innovative concepts because the costs would vary greatly with respect to the system size, scope, and complexity of changes; the existing planning and analysis activities; and the human resources, equipment, and facilities available. The section on costs included in each concept description identifies the types of costs that would be incurred. The detailed planning and design stage will determine estimated costs and benefits.

Procedure for Updating the Recommended Innovative Concepts

By its nature, the state of the art of innovative concepts changes as new concepts are developed and successfully demonstrated and existing concepts are accepted as conventional practices. Therefore, it is necessary to have a means by which the innovative concepts recommended for consideration by transit systems in Virginia can be updated. It is recommended that the following procedure be used. A person should be assigned the responsibility for periodically (every 2 years) reviewing the literature and recommending any applicable innovative concepts for implementation. The updating of the innovative concepts should require a small amount of effort compared to this effort to develop an implementation program. The Public Transportation Division is planning an information exchange program that may serve as a mechanism for disseminating the updated recommended innovative concepts. Otherwise, the designated person should be responsible for disseminating the updated information after it is reviewed by the Public Transportation Division.

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A periodic update of recommended innovative concepts will continually provide the state of the art of innovative routing and scheduling concepts. In this manner, transit operators in Virginia will be kept up-to-date on methods of increasing ridership and reducing costs. The gap between the development and implementation of successful innovative concepts should thus be eliminated, because current information will then be available to the transit operators.

SUMMARY

After an evaluation of the innovative concepts, five innovative concepts were found to be applicable for transit systems in Virginia based on route structure, system size, and routing and scheduling problems. The innovative concepts include (1) a procedure to redesign transit routes and schedules in smaller systems, (2) methods to improve short-range transit planning, (3) the planning and design of a timed transfer system, (4) planning and design guidelines for a transit center-based transit system, and (5) transit operator guidelines for transfer policy design. A program of implementation that included descriptions of the five concepts and how to plan, design, and implement the concepts, the recommendations for implementation of the concepts, and a procedure for updating the implementation program was developed.

RECOMMENDATIONS

Based on the results of this research, the following recommendations are made.

1. The implementation program developed in this study should be adopted by the Public Transportation Division to assist transit operators in Virginia in improving the efficiency of their operations by increasing ridership and reducing costs.

2. The Public Transportation Division should encourage transit systems to consider the recommended innovative concepts and provide financial assistance for planning, design, and implementation.

3. The planning, design, and implementation of each recommended innovative concept should be conducted as a pilot test and be initially limited to no more than two transit systems. Knowledge gained in the implementation experience would be very beneficial to other systems interested in implementing a

particular concept. Also, where computer software development is needed, a software package may be developed that is transferable to other transit systems.

4. The author of this report should assist in the implementation program by monitoring and evaluating the planning, design, and implementation of the innovative concepts.

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