Redesigning Urban Transit Systems: A Transit-Center-Based Approach

JERRY B. SCHNEIDER AND STEPHEN P. SMITH

Current metropolitan travel patterns in American cities are examined. The inability of highly downtown-focused (radial) transit networks to meet metropolitan travel desires in American cities is described. In addition, the limitations of the grid network approach to route planning are critiqued. A transit network that is designed to converge on a few strategically located transit centers is recommended as having the greatest potential to serve the multidestinational travel demand that characterizes American cities. A planning framework designed to aid planners in the preparation of plans for a transit-center-based transit system is outlined. Its key element is the strategic location of a few transit centers at major activity centers. Regional shopping centers are suggested as ideal sites for transit-center locations. The center-based transit network is assessed critically from operational, financial, and political perspectives. It is concluded that the development of 400-500 transit centers during the 1980s could materially aid the revitalization of transit systems in most American cities.

For the past 20 years or more, most of our large urban areas have been decentralizing rapidly and becoming less dense. As office, industrial, commercial, medical, and entertainment activities have followed suburban population growth to the outer city, a polycentric urban form has evolved that is made up of many concentrations of activities throughout the urban region. As a result, the central business district (CBD) is no longer the single focus of activity in an urban area but has become one among several important activity centers. This evolving land use pattern has produced a regional travel pattern that is much more diverse and less concentrated in a few radial corridors.

Most urban transit systems are still oriented to providing a high level of service to only the downtown in American urban areas. Unfortunately, travel to the downtown typically accounts for less than 10 percent of the total urban travel market in American cities. Consequently, most American urban transit systems are competing directly for, at most, a 10 percent share of the regional travel market and are essentially ignoring the other 90 percent of the market. Clearly, transit's share of the regional travel market cannot be expected to increase significantly (or at all) as long as it continues to focus service only on the CBD while ignoring the several other important destinations in the urban region.

The variety of transit networks that have been operationalized to serve public transportation needs has been very limited. Most transit networks operating in U.S. cities are designed to serve well only the commuter work trip to the CBD. Typically, the routes fan out from the CBD to the suburbs in a radial manner.

The downtown represents the only significant transfer point in such radial networks. This situation is changing somewhat in a few cities with the adoption of the crosstown routing concept, when important cross-radial desire lines are identified and service is designed to meet that demand. But overall, radial networks have been retained over the years by transit operators and planners who still do not believe that a fixed-route service can be designed to serve a variety of regional destinations effectively and economically or that people making non-CBD trips would patronize nonradial service if it were provided.

Given this transit planning perspective, radial systems are extremely limited in serving multidestinational travel. Most riders who desire to reach non-CBD destinations in a radial system are required to travel to the downtown, transfer, and then travel back out again to the final destination. A rider seeking a destination that may be no more than 3 km (2 miles) from his or her origin may be forced to make a 15-km (10-mile), 50-min transit trip. Clearly, this is not a service that is likely to capture a significant share of the non-CBD-bound travel market.

A more recent and relatively uncommon approach to regional transit network design is the grid concept. Rather than focusing service on the CBD, the grid offers north-south, east-west service connections to most regional destinations. The grid network is characterized by two sets of parallel routes spaced at regular intervals, each of which operates along a fairly straight path. Routes are developed as elements of an interdependent, integrated system. In a grid system, a great deal of importance is placed on the transfer. With a single transfer, the rider can reach almost any major destination with little circuitous travel; without the transfer, a rider is severely limited in the number of destinations available. However, it has been demonstrated that, if riders are to be induced to transfer, they must be able to do so quickly and easily, since the grid relies heavily on the transfer. It is therefore critical that efficient, convenient transfers be provided with minimal effort to the rider.

Unfortunately, the financial resources needed to operationalize a regional grid network that permits efficient transfers are so substantial as to make such an areawide system economically infeasible. Thus, the practical applicability of grid systems is limited to those areas of a region that have population, employment, and commercial densities that could support 10- to 15-min, day-long headways.

Whenever possible, a grid network should be developed for those areas that are able to support the level of service necessary to efficiently operate a grid. However, for the remainder of the region, the system must be designed to revolve about a few strategically located destinations if transit is to gain a share of the non-CBD-oriented travel market. The purpose of this paper is to present a framework for planning a transit system that could serve the multidestinational travel needs of people living in suburban areas in an efficient and effective manner. The main thrust of our argument is that the design of a regional transit system should be based on a set of strategically located major activity centers. Each of these locations should be provided with a transit center at which a high level of synchronized service is provided. Each transit center would be the focal point of transit activity for a subregion of the metropolitan area, and patrons would know that almost any destination in the region could be easily reached from any transit center.

Three types of routes would converge at each transit center: local, radial, and circumferential. The local routes would be designed to carry riders from their homes to a nearby transit center.

The radial routes would connect the transit centers directly with the CBD by means of limited-stop, high-frequency service. Circumferential routes would link the suburban transit centers with each other and with other major activity centers.

Like the grid, the routes of such a system would be developed so as to operate as an integrated system. Convenient transfers would be vitally important in such a system, and portions of the service would have to be timed at transit centers to make transfers as easy, quick, and comfortable as possible.

The design of a center-based transit network would be tailored to match the existing regional land use pattern and would have to be carefully developed by the transit operator, planners, and elected officials. Land use patterns and topography vary greatly from region to region, as do regional travel patterns. This makes the specification of design recommendations difficult and forces them to be general in scope. However, some general guidelines have been developed to aid in the preparation of a plan for a polycentric transit network.

This paper outlines and briefly discusses a process for planning and designing a transit network based on a set of strategically located transit centers. Our approach is based on three key points. The first is that every urban region includes several major activity centers that generate substantial amounts of traffic and that, although the CBD may be the largest and most important of such centers, it is no longer the only significant destination in the region. The second point is that fundamental transit-rider behavior can be altered from a "destination" to a "direction" orientation. The basic idea here is that people would rather be moving toward their destination than waiting for long times for nontransfer, and often circuitous, service. The third point is that, given a set of transit centers, a route-schedule plan can be designed that will provide the desired level of service. Getting three types of routes to pulse regularly at a set of transit centers is not an easy task, but it is within the capability of today's planning methods.

Some guidelines for the planning and design of a transit-center-based transit system are presented. These guidelines have been derived from a synthesis of 22 case studies. Table 1 gives the classification of the case in each city (these case studies are available from us as separate documents).

PLANNING AND DESIGNING A CENTER-BASED TRANSIT SYSTEM

Smith (1) has devised a six-step process that can be used to prepare a plan for a transit-center-based system in a large metropolitan region. These six steps are identified below and are then discussed in order:

1. Identify an area or areas where a grid system could be efficiently operated. Generally, this area will be near the CBD and very limited. Identify north-south, east-west corridors to be served by grid routes.
2. Select the number and locations of the transit centers on which the remainder of the system will be based. Use well-known major activity centers whenever possible. Define a primary service area around each transit center identified.
3. Divide the metropolitan area into subregions based on the primary service-area boundaries defined above. Note that the area to be served by a grid network is also a separate subregion. Identify other major activity and employment centers located in each subregion, and classify them as to their regional or subregional importance.
4. Analyze the travel patterns within each subregion and between subregions, by trip type and time, using the best available origin-destination (O-D) data. Determine which travel patterns, in space and time, are appropriate markets for transit service.
5. Design alternative route-schedule plans for those local, radial, and circumferential services judged to be high-potential markets. Evaluate the alternatives and select the plan that best meets the objectives of the various interest groups in the region.
6. Devise an implementation plan that is phased and prioritized.

Figure 1 shows what the results of the first three steps should look like.

Identification of Areas That Could Support a Grid System

Before attempting to delineate a grid service area, the planner must identify a logical set of grid-type streets on which service should be operated. These streets need not form a perfect north-south, east-west pattern but must allow reasonably smooth north-south, east-west bus movement.

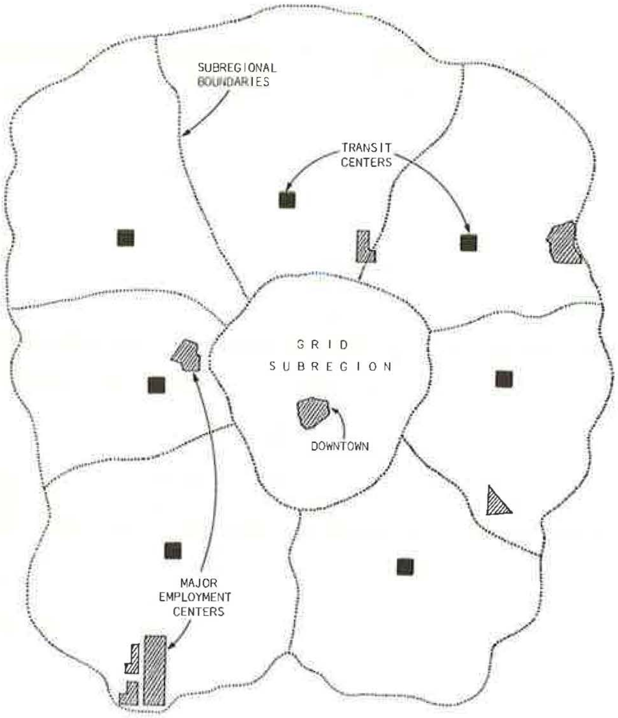
Once the planner is assured that the street system can support a grid system, he or she should define the specific area that could support grid service. The most important requirement is that densities of population, jobs, retail, and other activities be high enough to generate high levels of ridership to a multitude of destinations so that 15-min or shorter headways can be supported. Since such densities will invariably be greatest in the central part of a metropolitan area, the planner should begin with the CBD and work outward, looking for noticeable decreases in these densities.

Generally, the planner will have a good intuitive feel for the dimensions of this area because current rides per capita will typically far exceed the areawide average. Although the densities needed to support a grid system will vary from city to city, it is recommended that the grid service area be

Table 1. Case studies of transit centers.

System Status	Cities with Single Center	Cities with Multiple Centers
Existing and operating	Brockton, Massachusetts; Boulder, Colorado; Bellingham, Washington; Norwalk-Westport, Connecticut; Sacramento, California; Toronto, Ontario, Canada	Portland, Oregon; Nassau County, New York; Edmonton, Alberta, Canada; Vancouver, British Columbia; Hannover, Federal Republic of West Germany; New Delhi, India
Planned	Eugene, Oregon; three Iowa cities	Tacoma and King County, Washington; Santa Clara County, Los Angeles, Orange County, and San Diego, California; Denver, Colorado; London, Ontario, Canada

Figure 1. Results of initial stages of planning process for a center-based transit system.



extended outward from the downtown to those locations at which densities and rides per capita drop off significantly.

Selection of the Number and Locations of Transit Centers

A second important step to be taken in designing a center-based transit network involves selecting the right number and locations of the transit centers around which the route and/or schedule alternatives will be designed. The key to this step lies in locating a logical number of major points that effectively use popular, well-known locations that are strategically placed and properly spaced. By doing this, the planner can serve both destination- and direction-oriented travel, since the same local bus route that is used by some to reach a particular activity center can serve others who wish to use the express service from it to other destinations. It is anticipated that a rider using a particular route to reach the transfer point/activity center for a specific purpose will come to realize the ease with which that route can be used for other purposes and thus be encouraged to use the transit system more extensively.

Ideally, the transit centers should be in locations that (a) generate a good deal of activity throughout the day, (b) are spatially separated in a relatively even manner throughout the region, and (c) are well known and easily remembered. By locating a transit center at a busy location (e.g., a regional shopping center), a reasonably high level of service can be justified. This higher level of service will permit the transit system to serve a broader variety of markets and use the upward spiral concept, which states that, the greater the use of the transit line, the easier it becomes to provide better and cheaper service.

It is also critical that the transit centers be well distributed with respect to the population and employment distributions of the region. Ideally, one transit center should be allocated to every identifiable population cluster or community to minimize the distance between the population and the transfer point. Unfortunately, it is both operationally and financially impractical to have a large number of transit centers if the transfer is to be made efficient. Therefore, it is recommended that only one transit center be located in each subregion that is to be served.

Ideally, a local feeder bus should be able to perform a round trip in a minimum of 30 and a maximum of 60 min. Local routes that require longer travel times will be both difficult to schedule so as to meet simultaneously at the transit center and too long for many to use as a feeder service. Assuming a 19-km/h (12-mile/h) average bus speed and 5 min of layover at either end of the route, these travel times translate into route lengths of 3 and 6.5 km (2 and 4 miles), respectively.

Transit centers should also be located at appropriate distances from each other throughout the urban region. If transit centers are located close together, route overlap, scheduling difficulties, and unnecessary duplication will result. Competition between centers is counterproductive and should be discouraged by locating them at reasonable distances from each other.

Assuming an average speed of 40 km/h (25 miles/h) for buses providing service between transit centers, the maximum route distance between adjacent transit centers should be no greater than 13 km (8 miles). The minimum distance between two transit centers would be 6.5 km (4 miles) if a local service area with a 3-km (2-mile) radius is required.

The transit centers should also be located to maximize their accessibility. Direct access or nearby freeway or major arterial access is often important to the effective scheduling and operation of a transit center. This permits the regional routes to maximize the speeds at which they operate so that faster and more efficient service is provided to regional destinations from a particular transit center. This also allows fast and efficient access for those who wish to reach the transit center by automobile or another transportation mode.

Finally, whenever possible, the transit centers should be located at very well-known and easy-to-find locations in the urban area. A highly visible location will improve the perceived accessibility of the transit center to the user. More important, the locational pattern of the transit centers can be memorized more easily by riders if they can identify them with regional landmarks. Most regional activity centers are fairly well known and visible to the public. However, some (e.g., regional shopping centers) are better than others in this respect. When the locational pattern of a region's transit centers is made easy for riders to identify and memorize, the transit system becomes easier for them to understand and use.

With these locational objectives in mind, the planner should seek to locate a logical set of transit centers. CBDs, whether urban or suburban, can be ideal locations for transit centers, but the planner may experience some difficulties in determining the most appropriate transit-center locations for the remainder of the region. It is recommended that the planner begin seeking non-CBD transit node locations by first identifying and mapping the major shopping centers in the region. Regional shopping centers will generally provide ideal locations for transit centers because they typically satisfy the locational requirements of transit centers very effectively (2,3). For our purposes, regional shopping centers are defined as planned projects that have as a principal tenant at least one department store branch (usually two) with more than 13 500 m² (150 000 ft²) of gross store area. The size of such shopping centers will typically range from 27 000 to >90 000 m² (300 000 to >1 000 000 ft²) of gross leasable area.

Regional shopping centers offer ideal locations for transit centers for the following reasons:

1. A regional shopping center with 27 000 m² of gross leasable area will attract, on the average, 13 400 daily person trip ends, and this represents a substantial travel market that transit should seek to share with the automobile.
2. As a result of market forces, regional shopping centers are usually well located with respect to the regional population and other competing facilities.
3. Regional shopping centers are also generally well located with respect to a region's freeway and highway network.
4. Regional shopping centers are visible, well known, and easy to find.

Clearly, there will be instances in which a regional shopping center will not be available or practical to use as a transit focal point. In these cases, other major activity centers should be selected as transit-center sites. There will also be some situations in which two or more shopping centers are located close to each other and neither emerges as the clearly preferred location.

Selection of Subregional Boundaries

Once a set of transit centers has been located, whether at regional shopping centers or at other activity centers, the next step involves the definition of the area around each transit center within which local service should be extended. The resulting transit-center service regions should constitute the subregions on which travel and market analyses will be based.

Subregional boundaries can be determined in a variety of ways. Shopping-center trade-area boundaries, circulation boundaries, and governmental jurisdiction boundaries represent only a few of the possibilities available to the planner. The use of regional shopping centers as transit-center locations suggests that subregional boundary definition begin with an identification of the primary trade area around each designated shopping center. These trade areas typically cover an area with a radius of 6-8 km (4-5 miles), or 15 min of driving time, and are well known to mall managers. Once these trade areas have been identified, it is recommended that their boundaries be adjusted to conform to the following criteria:

1. Boundaries should enclose the entire transit service region.
2. Boundaries should conform as closely as possible to the areal limits associated with 30- to 60-min bus travel times.
3. Boundaries should recognize the region's natural and man-made barriers to travel (e.g., rivers, hills, canyons, and freeways).
4. Ideally, each subregion should contain the following activities and opportunities (listed in order of importance): (a) substantial residential development (25 000-100 000 persons), (b) a regional shopping center, (c) significant employment centers (e.g., office sites, industrial sites, and research parks), (d) health facilities and services, (e) educational centers, and (f) entertainment and recreational opportunities.
5. Land use concentrations, whether residential, industrial, or commercial, should not be divided by boundaries.
6. Boundaries should, when practical, conform to data-collection zones--most important, to census-tract boundaries.

Clearly, subregional boundary definitions will not be able to satisfy all of these criteria all of the time. However, these guidelines should afford the planner helpful direction in defining them. Each region will have to rank the importance of these criteria according to stated land use and transportation planning objectives so that in the case of trade-offs the more important criteria can be represented by the boundaries selected.

Travel-Pattern Analysis and Market Segmentation

Once the metropolitan area has been divided into transit-service subregions, travel patterns within and between the subregions should be examined. The travel-pattern analysis is conceptually simplified, since only two or three types of travel must be examined: travel occurring exclusively within a subregion (local travel), travel going from one subregion to another, and travel from the subregions to the CBD. As an example, Table 2 gives travel volumes between and within subregions in the Minneapolis-St. Paul urban region as observed for 1970 and as forecast for 1990 (4). Clearly, the non-CBD-destined travel volumes are very large and represent a market that transit should try to serve more effectively.

By using O-D data, the planner should segment these three markets into components that it is

Table 2. Travel volumes within and between subregions in the Minneapolis-St. Paul region for 1970 and 1990.

Analysis Period	Trip Orientation	Home-Based Work Trips Number (000s)	Home-Based Work Trips Percent	All Other Trips Number (000s)	All Other Trips Percent	Total Number (000s)	Total Percent
1970	To CBDs	192	18	219	6	411	8
	Within subregions	402	37	2415	62	2817	57
	Between subregions	487	45	1265	32	1752	35
	Total	1081		3899		4980	
1990 forecast	To CBDs	230	13	310	4	540	6
	Within subregions	640	36	4100	56	4740	52
	Between subregions	890	51	2930	40	3820	42
	Total	1760		7340		9100	
Change (1970-1990)	To CBDs	+38	-5	+91	-2	+129	-2
	Within subregions	+238	-1	+1685	-6	+1923	-5
	Between subregions	+403	+6	+1665	+8	+2068	+7
	Total	+679		+3441		+4120	

possible to serve with transit. This market-segmentation process is very important. It should define the demand side of the areawide transit planning process and should guide the design of the route and schedule layout at a subsequent stage in the process. Particular attention should be given to defining the time characteristics of these travel patterns, since much of the travel within and between subregions occurs in the off-peak period.

In addition to defining travel desires, the planner should develop a series of descriptive profiles concerning the sociodemographic and land use characteristics of each subregion. These profiles should include but not be limited to (a) population counts and breakdowns by sex and income, (b) population and employment densities, (c) the number of elderly and handicapped persons, (d) the growth potential in various parts of the subregion, (e) employment locations and residential locations of employees, (f) characteristics of automobile ownership and fleet mix, and (g) major arterials and potential transit corridors. Such information should be gathered for each subregion to assist in the preparation of subregional forecasts and to aid in the longer-range route-planning process.

Design of Alternative Route and Schedule Plans

As discussed previously, three types of routes should be laid out that serve and connect the transit centers with all major destinations in the region. The local route structure should be designed to perform a majority of the collection and distribution functions of the system. The structure of these routes must be laid out very carefully if the system is to succeed. It is therefore imperative that these routes be designed to match travel patterns as closely as possible.

The local routes must provide for three basic functions: (a) to operate as a feeder system, carrying riders from their homes to a transit center; (b) to carry riders from their homes to various destinations within the subregion; and (c) to carry transferring riders from the transit center to other destinations in the subregion.

The primary focus of the local route network throughout the day should be on the transit centers of a region. The secondary focus of these routes could change with changes in the travel pattern between peak and off-peak periods. Two sets of fixed routes could ideally be developed to serve peak and off-peak demand separately. During the off-peak period, local routes should be designed to connect spatial concentrations of employees with the transit centers and employment centers identified during the analysis of travel patterns.

The planner should strive to ensure that local routes have peak-hour headways of no more than 20- and 30-min off-peak frequencies. Because the local routes will operate primarily in suburban areas where development density and transit demand will be generally moderate to low, the planner should emphasize good frequencies as opposed to extensive coverage with poorer frequencies. This is based on the assumption that a majority of suburban riders using a local route will be "choice" riders (i.e., riders who have a car or access to one but opt to use transit) who will find good frequency of service more attractive than extensive coverage. This is not meant to imply a system of only a few routes operating at very high frequencies but rather that frequency and coverage levels should be balanced somewhat in favor of good frequencies.

Because headways during off-peak periods are likely to be greater than 15 min, the routes should be timed to meet at the transit centers. It is suggested that the planner begin with a 30-min pulse cycle and 5-min dwell time for the routes at the transit node and then adjust these times if necessary to most appropriately serve local demand. The planner can begin with a 30-min headway cycle as a maximum and effectively shorten it if necessary in terms of even divisors of 60 min (i.e., 10, 15, 20, and 30 min). Such intervals are easily remembered by riders and drivers and should be used for schedule design.

If route lengths are carefully controlled, timed transfers can be effectively achieved. It is highly recommended that no local route operate for a one-way distance greater than 6-8 km (4-5 miles). Any local route that exceeds this distance will have difficulty meeting the schedule of other routes. If the boundaries of a subregion have been properly determined, controlling route length should pose little problem.

It is also recommended that the lengths of local routes be as uniform as possible. It is far easier to schedule a series of routes of approximately equal length to meet simultaneously than a series of routes of differing lengths. This objective may be difficult to achieve because the market within a subregion is not likely to be circular and will, if based on the primary trade area of a shopping center, often be skewed away from the region's CBD. Natural topographic barriers may also pose problems for the planner trying to design a set of routes of roughly equal length that are designed to arrive at a certain point simultaneously. These are problems that will have to be solved separately for each subregion. It may be that some routes simply cannot be efficiently scheduled with the rest of the local network in a subregion without providing substantial layover. In these cases, the planner should not attempt to force that route into a schedule that it cannot maintain. If only one route of a local network cannot be effectively timed, the remaining routes should operate on a timed basis. However, if more than one route experiences problems with adherence to a timed schedule, the planner should consider not using the timed-transfer concept in that region.

Straight, clear routes should be developed to the extent possible to serve local demand. Thelen and others (5) found that no single local routing pattern could be recommended that would effectively serve different areas. Relative costs, coverage areas, and travel times were evaluated for four different hypothetical subregions and four basic local-route designs: narrow-loop routes, wide-loop routes, line routes, and meandering routes. Line routes were found to offer the best travel times but were generally the most expensive to operate. Loop routes were discovered to provide the best subregional coverage but had the poorest travel times. The meandering routes were found to provide a reasonable level of area coverage but had very poor travel times. More important, the narrow-loop and line routes were determined to provide the best connectivity to a transfer point. It is consequently recommended that the planner pursue these route types for providing local route service. However, each configuration clearly involves tradeoffs that will have to be dealt with locally. The decision on which route pattern to use in a given situation should be based on explicit objectives that acknowledge financial constraints and the service needs of the area. Figure 2 shows the hypothetical region used in Figure 1 with a local route design added.

A radial network of trunk routes should be designed to connect the outlying transit nodes with the region's CBD. A limited-stop service should be

Figure 2. Centers and local routes for a center-based transit system.

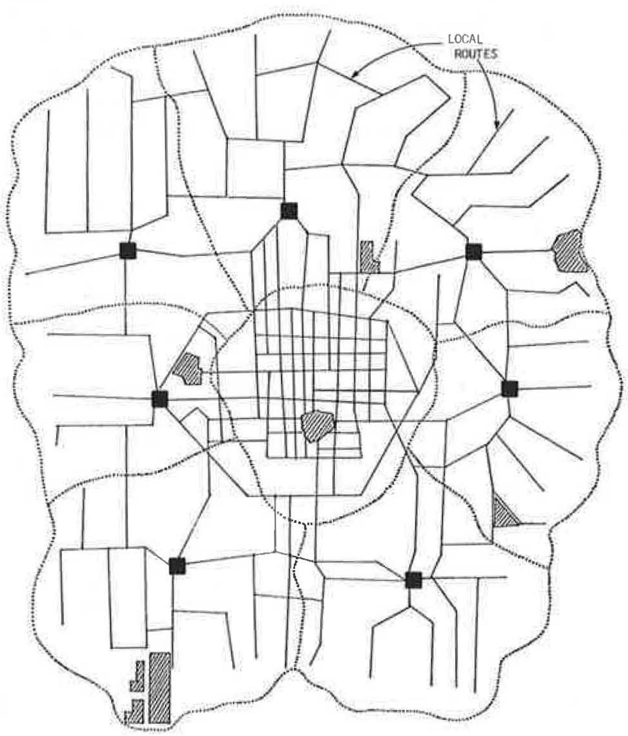
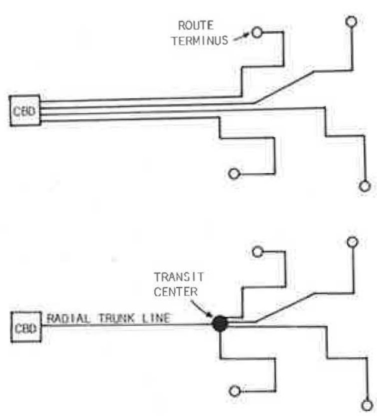


Figure 3. Radial service before and after emplacement of a transit center.



provided on these routes, and headways should be short, especially during peak periods. To the extent possible, these routes should operate on freeways or major arterials to maximize the speeds at which the buses performing this service can operate. Good bus speeds are very important on radial trunk routes. Frequencies should be fairly high. The number of buses required to provide such a high quality of service is overwhelming unless bus speeds are also high.

Trunk routes should be developed by combining several existing CBD-bound radial routes. This will result in fewer radial routes, each with a higher level of service. The number of buses reassigned to such radials will permit a good frequency of service between the transit centers and the CBD. Figure 3 shows the radial-route structure before and after application. The U.S. Department of Transportation (DOT) has conducted studies of this idea, which it calls the "zoned bus concept" (6).

The planner should attempt to design radial trunk routes that emulate the service characteristics of a rail rapid transit line. Good speeds and frequencies probably require that an ambitious program of priority traffic management techniques be formulated to provide the trunk routes with clear, unobstructed paths between the transit centers and the CBD. Special transit-only on and off ramps, special freeway and arterial lanes, and signal preemption may all be needed to allow such a service to be effectively operated.

Circumferential routes should be laid out to connect the various outlying transit centers in the region. The secondary objective of these routes should be to provide peak-period direct service from the transit centers to designated outlying employment centers. For either objective, it is critical that the planner recognize that a large number of the riders on these routes are likely to be choice riders. Circumferential routes should be designed specifically to provide a quality of service that is competitive with the automobile. This can be accomplished primarily by improving the speeds at which the buses providing the service can operate as well as their schedule convenience.

Bus speeds on circumferential routes can be optimized in three ways: (a) by maximizing the express portion of the trip by strictly limiting the number of stops the bus must make, (b) by operating the bus along a freeway for as great a distance as possible between the route's origin and destination, and (c) by using off ramps. It is suggested that the local portion of a circumferential route (i.e., that portion of the route during which stops are made and the bus operates along local streets) generally be no more than 3 km (2 miles) long. While developing a "transit planning framework" for the Denver Regional Transportation District (RTD), R.H. Pratt and Associates found that, if the local portion of an express route was greater than 3 km long, the route's competitiveness with the automobile was greatly diminished, primarily because the average speed of the bus is reduced so much (7).

Circumferential routes can be conveniently scheduled if they are timed to meet with local routes at the transit centers. Because intersuburban transit travel demand is not likely to be great enough to justify and support good frequencies between the transit centers, it is critical that the regional routes be scheduled to meet with the local routes. Because circumferential routes generally cover a greater distance than local routes, they may be difficult to schedule to meet with the local routes. If they are able to operate primarily in an express mode, along freeways or major highways, this scheduling problem can be substantially reduced.

The planner is also likely to encounter problems when structuring a circumferential route schedule to meet with local routes on a timed basis at more than one transit center. This may require the local-route schedules to be adjusted somewhat. It may also be necessary to schedule some layover time for the circumferential routes at the transit center(s) in order for the timed connection to work. Clearly, the planner must develop circumferential and local routes in parallel if timed transfers are to be scheduled effectively.

DOT is currently studying the application of a circumferential routing concept designed to connect the major non-CBD activity centers of a region. This concept has been labeled "beltway transit service" (BTS) and involves an express or limited-stop service that operates for a significant portion of its route over a suburban circumferential freeway or other highway that offers relatively high operating speeds (8).

Two routes will typically provide BTS service, one operating clockwise and the other counterclockwise along the circumferential roadway. These routes will operate in a complete circle, thereby allowing the rider to reach any of the designated activity centers without a transfer. The only stops provided with such a service would be located at the transit centers. The BTS concept has been effectively operationalized in New Delhi, India, where it has served as a key component of a network restructuring that has permitted the transit system to carry 40 percent more riders with only a marginal increase in fleet size.

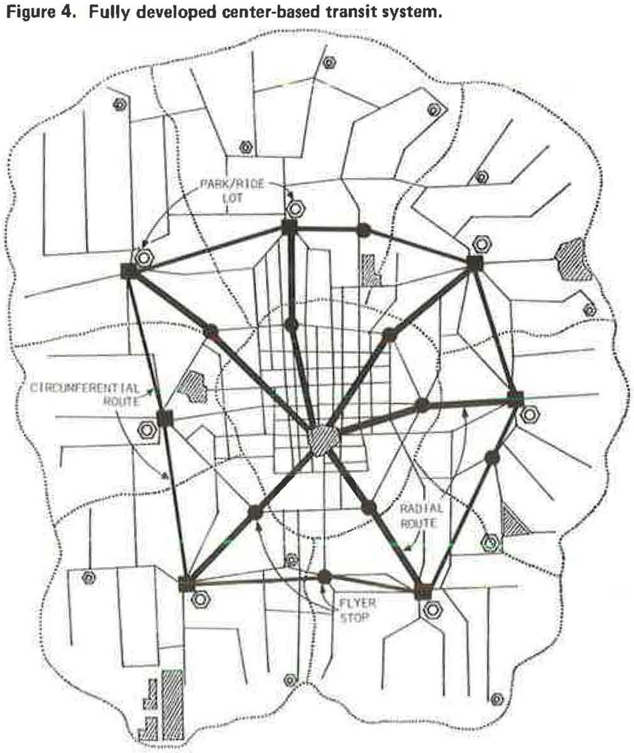
For the BTS concept to be incorporated effectively into a transit-center system, two requirements must be met: (a) A circumferential or suburban high-speed roadway must exist in the region, and (b) the transit centers must be located near the high-speed roadway and its interchanges. The roadway need not follow a complete circle for the BTS concept to be applicable. Any freeway, highway, or combination that provides a reasonably direct line between several transit centers would suffice. The objective is to connect as many transit centers as possible by means of a single bus route without requiring significant route deviation.

Figure 4 shows our hypothetical region with a set of radial and circumferential routes added. Freeway-flyer stops have been located on some radial and circumferential routes. Park-and-ride lots have also been added to show a possible spatial relation between them, the transit centers, and the route structure. In general, park-and-ride facilities should be located adjacent to transit centers and freeway-flyer stops whenever possible.

Implementation Guidelines

The complete restructuring of a transit network in a relatively short period of time is financially infeasible. Meeting the requirements of converting a center-based transit network will require some additional expenses that a transit agency typically will not be able to afford in a short time (e.g., more buses, increased service hours, and, initially, road supervisors).

Figure 4. Fully developed center-based transit system.



It is suggested that the planner organize the implementation process as a market-penetration strategy. This means that the conversion process should be directed first at pursuing those travel markets that are most easily attracted to transit. The rationale for an incremental market-penetration strategy is straightforward. If the transit system appears to be experiencing trouble attracting riders from those markets that should be most easily captured, the entire plan should be reevaluated and adjusted as need be.

The planner might effectively organize a market-penetration strategy as follows. First, the region's major corridors of travel to the CBD that are proposed to be served by trunk routes should be identified. These corridors should then be ranked according to the volume of traffic each carries to the region's CBD. Transit centers should be initially located and built in the highest-volume corridors. For each radial corridor that has been identified for implementation, the local system feeding that corridor must be implemented concurrently. Local feeder systems must be implemented in concert with the trunk lines they serve.

All corridors to be served by radial routes and the affected subregions should be converted before any circumferential service is implemented. In converting to a center-based network, it is most important to establish first the basic network of local feeders to any trunk routes, primarily because these routes will probably carry a majority of the riders in a center-based network and because the CBD work trip, on which these routes should initially focus, is generally the trip most easily attracted to transit.

Once the trunk and feeder routes have been properly implemented, the grid (if desired) and the circumferential routes should be implemented. The travel markets served by these routes are likely to be the most difficult for transit to penetrate; thus, they should be the final series of routes to be implemented. It is recommended that the routes designed to connect the various transit centers of a region be implemented first. If a BTS type of route pattern is being implemented, both clockwise and counterclockwise routes should be implemented together.

Finally, the express services, which are designed to connect the transit centers directly with various regional employment centers, should be implemented. Once again, the order of such service introduction should be in accordance with the transit potential of the market.

At each stage of the implementation process, it is vitally important that the planner develop and use monitoring systems to ensure that prior expectations are being realized. The planner should be careful not to overreact if a particular part of the network is not operating as anticipated. After conversion, a certain amount of time (usually at least six months) will have to pass before trends can be accurately determined, primarily to allow both bus drivers and bus riders some time to become accustomed to the new system. Once a trend that is unfavorable to the operation of the plan has been properly identified, adjustments should be formulated and action taken quickly.

EVALUATION OF THE CENTER-BASED TRANSIT NETWORK

Strengths

Broader Penetration of the Regional Travel Market

In most cases, the CBD-bound work trip would have a higher level of service with a center-based transit system. Travel to non-CBD activity centers would be much easier. Suburban-to-suburban and intrasuburban travel would also be easier and faster. Overall, the higher level of service provided should allow a broader penetration of several markets by transit.

These attributes allow the center-based network to compete better with the automobile for both peak and off-peak travel markets. The ability of the center-based network to provide a good quality of off-peak intersuburban and intrasuburban service that is focused on major activity centers is the key to gaining ridership increases in the future. It is these travel markets that have yet to be penetrated much by transit. Clearly, the rider who uses the center-based system is encouraged to use it as an integrated system of routes, not as a collection of independent, unrelated, and uncoordinated services.

System Efficiency

The center-based network offers very good fleet-optimization possibilities. The suburban-urban bus-load imbalances that characterize radial networks should not prevail in a center-based network. That is, when long bus routes are designed that pass through both urban and suburban sections (as in radial networks), the bus will typically be underused in the suburban portion of the trip, where density and travel demand are lower, and overcrowded during the urban portion of the trip. The feeder buses serving the suburban areas can be designed to most effectively serve that demand, and the radial routes, which operate primarily in areas of greater population and development density, can be adjusted independently of the feeder system to better handle the higher demand. The extent to which such load balances are optimized will be a function of how well located the transit centers are. Conceptually, an optimal location would be one that is at the urban-suburban boundary of a region.

System speed should also improve in a center-based network, since the feeder buses are designed to perform the bulk of rider collection and distribution, thereby freeing the radial and circumferential routes to sometimes operate in limited-stop or express mode. Furthermore, it is often asserted that forcing traffic into channels or corridors will make possible high frequencies with high occupancy ratios. The radial-route portion of the center-based network is designed around this technique and can significantly improve the effective carrying capacity of the system.

As previously noted in this paper, the center-based network permits the transit system to exploit major trip-destination travel markets. Every route will serve a particular major activity center, which will provide a more equal distribution of riders to these centers among the various routes of the system. Off-peak ridership is also encouraged under these circumstances because the non-CBD activity centers on which the network converges are generally off-peak-oriented. These centers will typically offer substantial shopping opportunities and some entertainment, medical, and other services that generate significantly more off-peak than peak travel activity. The ability of the transit centers to handle timed-transfer service will also contribute to better off-peak ridership. Because headways are far shorter during the peak period, the efficiency of the transfer becomes much more important during this time period. Fast and efficient transfers during the off-peak period would encourage more riders to use the transit system. The center-based network thus offers a very good opportunity to reduce the imbalance between peak and off-peak system ridership. A more balanced peak to off-peak system load factor will substantially improve the performance of the bus fleet.

User Comprehension of Network

The amount of information required to use a center-based network extensively is very minimal:

1. Riders do not require schedule information for the radial routes because of the frequency of service. Thus, they can use this portion of the system as they would a rail rapid transit system.
2. To reach the transit center nearest their home, riders can simply use a local bus, since all of the buses provide direct service to the center. Riders would only require schedule information about the local route running nearest their trip origin.
3. The direct services connecting the transit centers permit riders to reach any of these points directly from this origin center. This tremendously simplifies the route information needed, since any bus performing this service will eventually reach all transit centers.
4. Elaborate information displays at each of the transit centers, showing the express routes and the local feeder system serving that center, can be financially justified. Entire system displays would not be necessary, since riders need only information concerning the local system that serves the transit center nearest their destination and the available express service to it. Once at the transit center, riders could determine the best route and departure time, figuring their trip as they go.
5. Because the center-based network relies extensively on timed transfers and the rider is assured that the transfer wait time will be minimal, schedule information concerning connecting routes is unnecessary.

Thus, the only information riders may be required to have to use the system effectively and extensively would be the schedule of the local route carrying them from home to the nearest transit center. Once at the transit center, riders can be assured of a direct and easy-to-identify connection to almost any major regional destination. The locational pattern of the transit centers can be easily memorized by most riders, and the easy recognition of these places provides reassurance that progress is being made toward the desired destination.

System Integration

The center-based concept requires substantial service integration at several locations in the region. It seeks to combine major transfer points with major activity centers and is consequently a framework for integrating a variety of transportation services with the transit system. Since all routes in the network are designed to converge on a series of activity centers, extensive service integration can be accomplished at each activity center/transit center. However, the number of routes serving a transit center will not be so great as to prohibit direct interface between the transit system and other forms of transportation (e.g., paratransit and intercity buses). The objectives of the center-based network and the requirements of service integration appear to be ideally matched, which indicates that this concept has a high potential for service integration.

Weaknesses

Opposition from CBD Interests

Downtowns have traditionally been the focus of transit service in metropolitan areas. The idea of placing transit centers at regional shopping centers involves breaking this tradition and may be opposed by those downtown interests that wish to see the status quo maintained. Actually, the center-based transit concept would increase the quality of service to the CBD, but it will not be easy to convince the downtown interests that such a result would occur.

Capital Requirements

Early evidence suggests that transit centers may cost an average of $0.5 million. If 400-500 such centers were to be built in the nation during the 1980s, as much as $250 million could be required to redesign most of the transit systems in the country. Although this is a small sum in comparison with the cost of even one heavy rail system, it will still not be easy to finance a development program of this scale.

It is also fairly clear that larger bus fleets would be required to operate the schedules required by a center-based transit system. The extent to which this is true is currently unknown.

Public Opposition and Confusion

Change always creates opposition from some quarters, and it should be anticipated that some members of the public will feel that the center-based approach will serve them less well than the existing system. The public should be involved from the beginning in discussions of the concept so that the new design maximizes the use of their knowledge and their desires for service. Such a public participation program will not make public acceptance more likely, but without it a change of the type proposed in this paper is unlikely to be adopted by the transit operator.

Opposition from Shopping-Center Owners and Managers

One should not assume that all shopping-center owners and managers will automatically welcome a transit center on or adjacent to their malls. Many mall people have had bad experiences with buses and the people who ride them and will be wary of proposals to place a bus facility of substantial scale on their property (even if it does not cost them anything). They will have to be convinced that the benefits will be greater than the costs before they are willing to give up any part of their vast parking areas.

Complexities of Schedule Design

The center-based concept will require timed-transfer service in some but not all locations. Designing a schedule that will meet timed-transfer requirements can be a very complex task. The scheduler should have access to advanced computer-based systems to assist in this task. Fortunately, such a system is currently available (9), but it is currently being used by only one transit agency in the country, the Chicago Regional Transit Authority, in the Chicago suburbs. If the center-based concept were to be widely applied, training programs would probably have to be established to help schedulers deal with this problem.

OVERALL ASSESSMENT

The center-based transit system is not a radical concept in that it simply involves using ideas that have evolved and been tested over the years in a somewhat different way. We have attempted to package these ideas in a way that matches better the evolving urban form and travel pattern of the modern metropolis. Changes in urban form have produced changes in travel patterns that are making traditional transit networks obsolete. The prospect is that problems of fuel price and availability will put increasing restraints on the ownership and use of automobiles, an additional factor that suggests that transit should begin to serve those destinations that have traditionally been totally served only by the automobile. We know of no significant indicators that suggest that the urban-form trends experienced in the past two decades will be significantly different in the 1980s and 1990s. The downtown will remain the most important destination for most transit agencies, but the proportion of all destinations that are not located downtown will continue to grow rapidly. If very fuel-efficient automobiles are produced and are purchased by large numbers of Americans in the 1980-2000 period, then any type of transit system will have a much more difficult time being successful. On the other hand, if the price of fuel continues to rise rapidly and a large number of people cannot purchase expensive new fuel-efficient automobiles, then the transit system can be expected to be called on to increase its service to non-CBD destinations throughout the metropolitan area. We judge the latter to be the more likely eventuality. Even in the former case, transit systems will have to be reoriented just to stay even, let alone grow.

This paper has attempted to synthesize and integrate several ideas that are currently being pursued around the country in a piecemeal fashion. In doing so, we have raised many questions that need answers. In our view, a series of simulations needs to be performed in a laboratory environment in order to provide a more detailed technical assessment of the center-based concept presented in this paper. The main question is whether costs would rise much more than revenue. Other technical questions dealing with system scheduling feasibility, fleet requirements, and user comprehension also need to be investigated in more detail. Information regarding political acceptability should also be gathered and analyzed in the near future. Experience is currently being gained in several cities around the country (and in Canada and elsewhere in the world) that will also be helpful in a more detailed assessment of the concept presented in this paper. Case studies of the location, size, and physical design of transit centers have recently been conducted and are available to assist in this continuing assessment.

History has shown that cities are constantly evolving but that public service systems tend to change only infrequently and then in rather massive ways. Perhaps the redesign of urban transit systems is about due for a quantum change as part of the growing trend that may lead to the "reindustrialization" of the country. The problem is the same: a lagging, largely obsolete way of doing things that needs to be updated and rationalized. If we wish to improve the role of transit in providing for the mobility needs of urban areas, center-based transit systems appear to offer a high potential for success.

ACKNOWLEDGMENT

This paper was produced as part of a research and training program in urban transportation sponsored by the Urban Mass Transportation Administration (UMTA). The results and views expressed here are ours and are not necessarily concurred in by UMTA. We wish to express our appreciation of UMTA's support of our research on the topic of transit centers. We gratefully acknowledge the graphics and editorial assistance provided by Barbara Blackman.

REFERENCES

1. S.P. Smith. The Nodal Transit Network: An Evaluation and Planning Framework. Department of Urban Planning, Univ. of Washington, Seattle, master's thesis, June 1980.
2. J.B. Schneider and S.P. Smith. Synchrocentered Transit Systems: The Challenge of the 1980s. Transit Journal, Vol. 6, No. 2, Spring 1980, pp. 39-48.
3. J.B. Schneider and others. Increasing Transit's Share of the Regional Shopping Center Travel Market: An Initial Investigation. Urban Transportation Program, Departments of Civil Engineering and Urban Planning, Univ. of Washington, Seattle, Res. Rept. 79-2, Aug. 1979. NTIS: PB 80-131 360.
4. Metropolitan Plan. Twin Cities Metropolitan Council, Minneapolis-St. Paul, 1978.
5. K.M. Thelen, A. Chatterjee, and F.J. Wegmann. Evaluation of Alternative Transit Routing Configurations in a Hypothetical Low-Density Area. TRB, Transportation Research Record 761, 1980, pp. 53-56.
6. B. Spear and others. Service and Methods Demonstration Program: Annual Report. Urban Mass Transportation Administration, U.S. Department of Transportation, Rept. UMTA-MA-06-0049-79-8, Aug. 1979.
7. A Transit Planning Framework. R.H. Pratt and Associates, Inc., Denver, CO, Jan. 1977.
8. R.H. Winslow and R. Shieldhouse. Beltway Transit Service: Express Bus Service on Circumferential Freeways. Technology Research and Development Corp., Arlington, VA, Sept. 1979.
9. The Transit Network Optimization Program (TNOP). General Motors Transportation Systems Center, Warren, MI, 1980.

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

Driver Selection and Training in Human Service Transportation Programs

FRANK W. DAVIS, JR., LAWRENCE F. CUNNINGHAM, AND DAVID MATTHEWS

In recent years, because of increasing personal transportation costs and a decline in available public transportation, human service agencies have found themselves spending more time and money transporting clients to and from essential human services. As a result, such agencies need increased knowledge about transportation. While agency managers often have a general understanding of basic transportation concepts, they lack an understanding of risk management and the key to a successful risk management program, the drivers. An analysis is presented that is designed to help the various human service agencies to identify (a) the passenger-assistance and driving skills necessary to transport specific program beneficiaries, (b) appropriate screening procedures for selecting drivers, and (c) various programs available to train drivers. Because human service transportation is so specialized, the qualifications and characteristics desired in drivers of human service vehicles differ considerably from those of drivers of other types of vehicles (such as truck drivers). Drivers for human service agencies should have an understanding and tolerant attitude toward others, patience, an agreeable nature, concern for others, and basic first-aid skills.

In recent years, human service agencies have moved into a void in the American transportation system--the provision of transportation services for the disadvantaged who can neither drive themselves nor use existing public transportation. Transportation programs of human service agencies, unlike traditional transportation programs, are mission oriented. Human service transportation programs are designed to provide target groups with adequate medical care, shopping facilities, nutritional services, and recreational facilities, the opportunities for which most people depend on the private automobile or traditional transit.

A recent study done by the University of Tennessee illustrates that a range of human service transportation options is important (1). The need for transportation services in general can be divided into seven distinct user segments:

1. Automobile users--Individuals who have driver's licenses, own automobiles, and can afford to operate their automobiles (although some individuals may require special controls);
2. Conventional public transportation users--Individuals without access to automobiles who are physically able to use public transportation, have conventional public transportation service available, and can afford to use the service;
3. Subsidized public transportation users--Individuals without access to automobiles who are physically able to use public transportation, have public transportation available, but are not able to afford the available service;
4. Expanded public transportation users--Individuals without access to automobiles who could use public transportation service if it were available;
5. Curb-to-curb users--Individuals without access to automobiles who physically cannot use public transportation but could use a service that came to their homes;
6. Door-through-door users--Individuals who are not able to leave their homes without assistance or escort; and
7. Ambulance users--Individuals who need ambulances and their paramedic escorts to take trips of any type.

Unlike public transportation companies (publicly