Planning, Implementing, and Evaluating a Timed-Transfer System in Portland, Oregon

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The development of multidestinational transit service in Portland, Oregon, is described, from both policy and operational perspectives, particularly the planning, implementation, and evaluation of a timed-transfer system in Portland's suburban Westside. The transit system in Portland developed with a radial orientation as did most systems in North America. In the 1970s, there was a major change in transportation policy in the Portland region that encouraged development of a transit system that would serve the more diverse travel patterns that had emerged in the area since the 1950s. Tri-Met staff began preparation of the first phase of this service reorientation in 1978, a timed-transfer system for the suburban Westside. Service was implemented in June 1979, and new transit ridership far exceeded expectations. Weekday ridership increased by 40 percent after one year of operation. More important, local travel within the Westside, particularly nonwork and nonpeak trips, increased dramatically. Several schedule adjustments were made during the first year of operation, especially on the trunk lines, to improve the reliability of transfer connections at the transit centers. Tri-Met has introduced additional timed-transfer service in other suburban communities as a result of the success of the Westside service.

The decade of the 1970s was, to a large extent, a time of rebirth for public transportation in Portland, Oregon. New subsidies from both federal and state governments and the establishment of a new public transit district provided for acquisition of new rolling stock and capital facilities as well as for larger operating and service levels. This expanded financial base also provided the opportunity for the transit district to expand the travel markets that it served. Of primary consideration here is the transition from a radially oriented transit system serving the downtown commuter that had developed historically in the Portland area to a multidestinational system conveniently serving many destinations and trip purposes. The financial realities of the 1980s require that the Portland transit system become more relevant to the needs of local travelers as well as provide service in a cost-effective manner. Both objectives can be achieved by a well-designed application of the timed-transfer concept.

This paper describes, from both policy and operational perspectives, the development of a multidestinational transit service in Portland, Oregon. Specifically, the paper focuses on the planning, implementation, and evaluation of a timed-transfer transit system in Portland's suburban Westside.

PLANNING

Policy Framework

Tri-Met has been the public transit operator in the Portland area (see Figure 1) for 12 years, since 1970. During this time, average weekday ridership has nearly tripled to 150 000 daily trips, the bus fleet has grown to 570 vehicles, and a 15-mile light rail transit project is now under construction. Although it carries less than 5 percent of all the trips within the three-county area that it serves, Tri-Met does reach a modal share of about 35 percent for those trips to and from the downtown business district. Public transit has been a partner in, and to some extent has encouraged, a revitalization of the downtown area that has included a $15 million transit mall completed in 1978 and an office and commercial boom that began in the mid-1970s and continues unabated into the 1980s. This proven success in serving a large segment of downtown travelers, in conjunction with other factors, has led to a regional transportation policy that calls for a greatly increased role for public transit in the next two decades.

This regional policy had its roots in the decision by local elected officials in 1976 to withdraw their approval for a proposed urban freeway through southeast Portland. Neighborhood livability, increased traffic congestion, the need for a strong downtown core area, and increased awareness of energy limitations all pointed the way for a strong transit system that could carry many kinds of trips to many destinations, not just the traditional radially oriented system that had developed in Portland and many other North American cities.

Tri-Met established this direction on a policy level in 1977, when it adopted long-term 1990 goals. The policy choice at that time was one of a strong growth and advocacy position for transit, a position supported by the transportation plan being developed by the local metropolitan planning organization. One of the major elements of the 1990 goals was that, in its expansion, Tri-Met would evolve toward a multidestinational transit system--that is, a system that served many destinations and not just downtown Portland. This policy direction was reaffirmed in 1980 when the Tri-Met Board of Directors adopted a new five-year transit development program (TDP). Basic to the TDP was a recommended service plan for 1985 that would significantly restructure Tri-Met's radial service pattern. For the higher-density areas of the region (primarily the City of Portland), a grid-type system of high-frequency east-west and north-south lines would be implemented. For the suburban areas, where lower densities could not support the service level required by a grid system, a timed-transfer system focusing on several transit centers was proposed.

Service Design

With the adoption of the multidestinational goals by the Tri-Met Board of Directors in 1977, the staff began development the following year of a service plan based on the timed-transfer concept to implement this policy (see Figure 2). In order to be successful, the timed-transfer concept must include several key elements. A trunk line connects a suburban community with the downtown core area. The trunk line generally operates with frequent service throughout the day and connects with local service lines at a transit center located in the suburban community. Schedules are designed so that the trunk line and local lines have timed connections at the transit center and thus transfer connections can be made conveniently from one line to another. The timed transfer is critical because the diverse travel patterns present in most areas require the traveler to use more than one bus line to complete a trip.

For several reasons, Portland's suburban Westside was identified as the first sector of the Tri-Met service district to be redesigned by implementing the new policy. The appropriateness of the Westside for this service redesign was evident because of the

Figure 1. Portland, Oregon, metropolitan area.

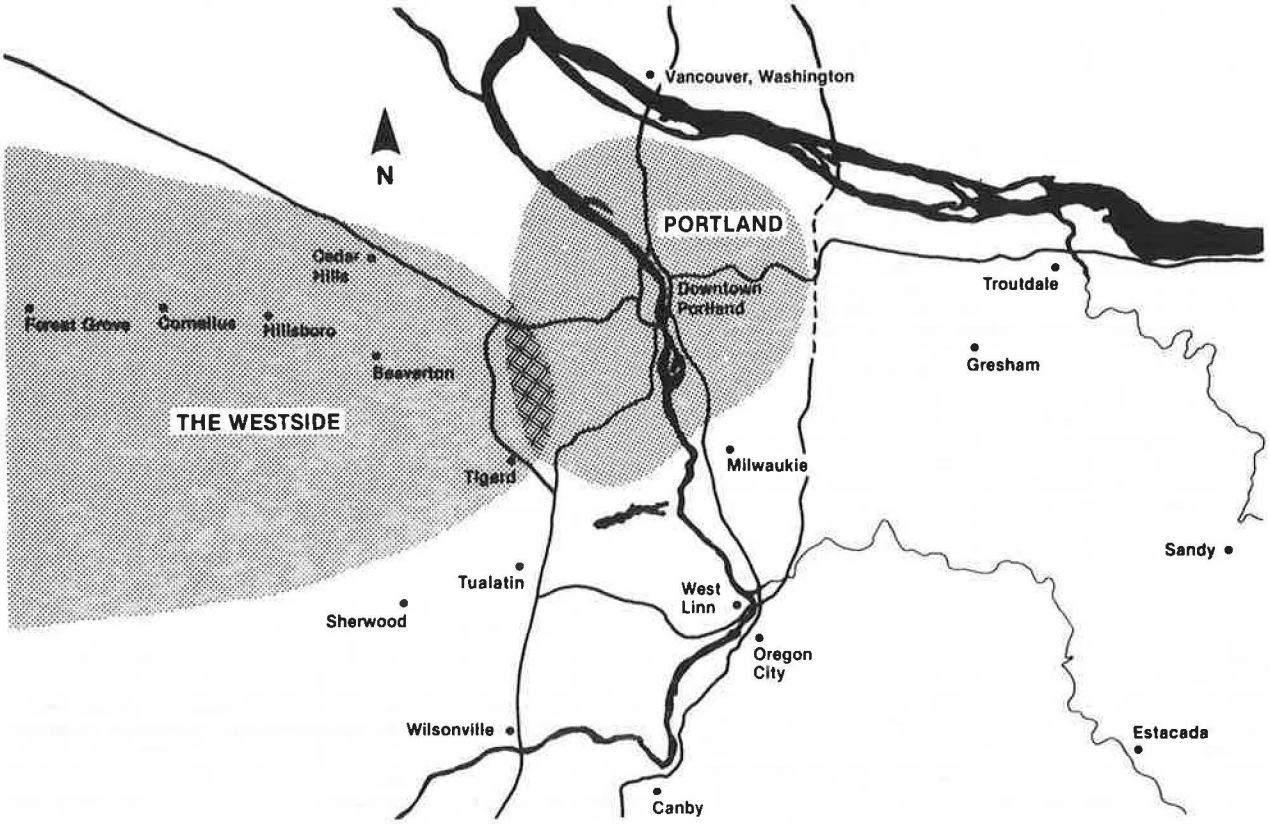
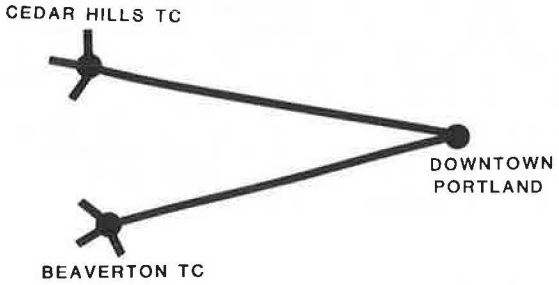


Figure 2. Timed-transfer concept.



rapid growth and changing land use patterns and travel patterns that had occurred over the past 25 years while, at the same time, the transit system in the area had experienced declining service levels and growing inefficiencies. The largest employment concentration in the region outside of the downtown (which included 12 000 jobs) was also developing in the Westside. In addition, there were several key suburban focal points that lent themselves well to the establishment of the transit centers necessary for the operation of timed-transfer service. Finally, whereas most of the existing Westside route structure needed basic overhauling, Tri-Met did have one major trunk line connecting downtown Portland with the suburban communities of Beaverton, Hillsboro, and Forest Grove that could be further developed in the timed-transfer concept as the key radial trunk line connecting with local service lines in the Westside.

A brief description of some of the travel characteristics of the Westside will help to clarify the deficiency in the existing radial system and why the timed-transfer system was needed. The area includes the cities of Beaverton, Hillsboro, Forest Grove, and unincorporated areas of suburban Washington County. Total population for the area in 1977 was 173 000, and employment was 49 000. Total person trips generated in the area averaged 788 000/weekday. Travel between the Westside and downtown Portland accounted for only 8 percent of these weekday trips (60 000); half of these trips (389 000) were internal Westside trips. The tables below give these daily trip data by type of travel movement and by mode:

	Avg Daily Trips	
Travel Movement	All Modes	Transit
Internal Westside	389 000	4 000
Westside to downtown	60 000	6 000
Other Westside	39 000	2 000
Total	788 000	12 000

Mode	Avg Daily Trips	Modal Split (%)
Automobile	776 000	98
Transit	12 000	2
Total	788 000	100

The orientation of the transit system, however, meant that downtown Portland was the only major destination conveniently accessible by bus. Of the 12 000 trips made each day on the bus in 1977 on the Westside, about 6000 trips were between the Westside and downtown Portland, which certainly emphasizes the disproportionate downtown orientation of the transit system. The modal share for transit for all Westside trips was less than 2 percent but was 10 percent for Westside to downtown travel. The modal split for internal Westside trips (by far the larg-

est travel market) was less than 1 percent.

By fall of 1978, a preliminary service design had been completed by Tri-Met staff. This design included two major trunk routes that would form the backbone of the new system. One would operate between Beaverton and downtown Portland, and the other would connect Cedar Hills with the downtown area. Transit centers, where the timed connections between the trunk lines and the local lines would occur, were proposed for both of these suburban communities. The local lines were designed to serve a number of new destinations that were previously without transit service, including several major Westside employment centers, a shopping center, and a recreation center as well as several residential areas. In addition, the restructuring of the entire service pattern greatly improved travel by bus to many areas in the Westside that had previously been served. This was accomplished primarily by more direct routings and improved network connectivity achieved through timed connections between routes at the transit centers.

Although improved service quality was a major concern, cost efficiency was also a critical factor in the service design. It is here that the timed-transfer concept may hold the greatest promise for transit service development. Prior to 1979, bus service to the Westside consisted of radial routes emanating from downtown Portland into Westside neighborhoods and activity centers. Many routes carried capacity loads during peak hours, but most had relatively light passenger loads during the off-peak. The result was that Tri-Met was spending a significant amount of money operating many radial routes to downtown at relatively poor service levels and carrying less than capacity loads. The timed-transfer concept provided the technique to eliminate the time-consuming and costly trip between the suburban center and downtown on most of the existing radial lines. This meant that operating hours were then available for productivity service on local lines linking key Westside destinations with good service levels. One trunk line rather than several radial lines could then provide the important connection from the suburban center to downtown.

The final service plan was considered by the Tri-Met Board of Directors in March 1979 and approved for implementation in June 1979. The elements of the plan included the following:

1. The timed-transfer concept would be used in the design of a completely restructured system of bus routes in the Westside, including two trunk routes and eight local routes. Service would be focused on transit centers in Beaverton and Cedar Hills.
2. New service to 12 000 Westside residents (a 10 percent increase) and 9000 jobs (a 27 percent increase) would be provided. Several major trip generators, including the region's largest employer, would receive new service.
3. Frequency of service on more than 50 percent of the major arterials in the Westside would be improved. Service levels would be maintained at existing levels on the remainder of the arterials.
4. There would be a general increase in travel mobility by bus with more local service and convenient transfers between lines.
5. The additional annual operations cost was estimated at $1 125 000. The total construction cost for the two transit centers would be $160 000. The new service would require 25 additional peak-hour buses.

IMPLEMENTATION

Schedule Design

The schedule design was probably one of the most critical aspects in the implementation of the Westside timed-transfer system because of the financial impacts of such a major change as well as the potential service impacts to existing bus patrons. Tri-Met staff had three major goals during the schedule design process to minimize these impacts:

1. Design reliable schedules based on thoroughly checked running times to ensure that the timed connections would indeed take place,
2. Provide sufficient capacity for all existing riders traveling to and from downtown Portland and sufficient additional capacity for new riders that would be attracted to the service, and
3. Accomplish the first two goals by using a minimum number of bus operators and vehicles so that the service would be both efficient and cost effective.

Each of these goals was addressed carefully in the final design of schedules.

To ensure reliable running times on the proposed Westside local lines, simulated trips using regular bus operators were made during both peak and off-peak periods. For the trunk lines, several ride checks were made to verify existing running times. Line profiles, measuring passenger on-off activity at each bus stop, for existing Westside services were determined so that estimates could be made of passenger loads for the new service. Passenger volumes were assigned to the new lines based on line-segment volumes of the existing service. These data were available by time period so peak-load requirements for the new trunk lines could be estimated. Finally, by using the constraints of the labor contract, new schedules were written that would allow for an efficient run cut. Attention was paid to the length of the schedule blocks (i.e., the platform hours required of each vehicle) so that split shifts could be controlled and overtime kept to a minimum.

Designing schedules is not unlike playing chess: Mistakes made early will often make good end results impossible. All of the schedules in a timed-transfer system are interrelated, and therefore decisions made early in the planning process have a definite impact on the final schedule design. For the Westside service, some of these decisions were

1. To use clock headways for the local lines based on policy rather than passenger volumes,
2. To use off-peak running times as the basis of the design for the local lines, and
3. To make departure times from the transit centers consistent throughout the day, seven days a week.

Clock headways and consistent departure times from the transit centers meant that the service would be more understandable and easier to use. Design of the local routes based on off-peak running times resulted in fewer routes to cover the service area. These factors all provided a very definite framework on which the schedules could be built.

Next, it was necessary to determine when the timed transfers or direct meets should occur. Several factors had to be considered before this could be determined, including

1. The most important destination to be served,
2. The most important route connecting that destination to the transit centers,

3. Travel time from the transit center to the primary destination,
4. The key arrival and departure times at this destination, and
5. Travel times and peak arrival-departure times for other major destinations.

Downtown Portland was still the most important destination to be served; the peak arrival time was just before 8:00 a.m. and the peak departure time just after 5:00 p.m. Since the line connecting Beaverton and downtown Portland was the most direct and heavily used line, travel times to and from Portland via this line were carefully checked and optimum morning departure and afternoon arrival times at Beaverton were selected. The other major destination to be considered by scheduling staff was a large employer in Beaverton just 6 min from the Beaverton transit center. Fortunately, most of the employees of this firm had flexible working time options so that times convenient for downtown Portland workers were convenient to most of these Beaverton-based employees as well.

Once the preceding information was developed, the next step was to build the schedule for the Beaverton to Portland trunk line, keeping in mind that a good share of the passenger activity would be focused at the transit center during the times the local buses were meeting. The trunk-line schedule was designed to include a mix of local stop, limited stop, and express service to provide the best service possible for passengers at the transit center and for passengers between the transit center and downtown Portland. (The service at the Cedar Hills transit center was developed on the same pattern as at Beaverton.)

Next, the schedules of the local lines were designed so that all lines (both trunk and local) would meet each other at the transit centers. One problem developed in the schedule design for the off-peak service, however. Because one of the three lines that connected both transit centers would be operating over a shorter route than the other two, not all buses could meet at both transit centers. This was accepted as a given, and the primary movement at each transit center was timed. Figure 3 summarizes the schedule design process.

Service levels based on policy headways were established for both peak and off-peak operation. Schedules were designed so that each line would meet at the transit center every 30 min during the midday and every 20 min during rush hours. Trunk lines were designed with additional service as necessary during the peak period to handle passenger loads. On weekends, the direct meets would occur hourly. Each of the local lines would lay over at the transit center for between 5 and 7 min to ensure reliable connections between all lines. The trunk lines were designed to lay over for 2 min, sufficient time for transfer connections but not enough to inconvenience through passengers.

Transit Center Construction

The physical focal points of the new Westside service were to be the two transit centers, one in downtown Beaverton and the other adjacent to the Cedar Hills Shopping Center. The timed-transfer system required that each bus be at its designated transit center at the same time. This meant that each bus must have its assigned loading bay and the ability to arrive or leave independently of all other buses at the transit center. A "sawtooth design", featuring angled rather than parallel loading bays, allowed this independent operation (see Figure 4). The Beaverton transit center included 13 bays, and the Cedar Hills transit center was designed with 6 bays. Bus passenger shelters and information signing were provided at each transit center. The transit centers were constructed completely with local funds for a total cost of $160 000.

EVALUATION

Beginning in Spring 1980, Tri-Met staff initiated a comprehensive evaluation of the Westside service that was designed to address a number of important concerns. The scope of the evaluation required the cooperation of several Tri-Met departments and in-

Figure 3. Schedule design process.

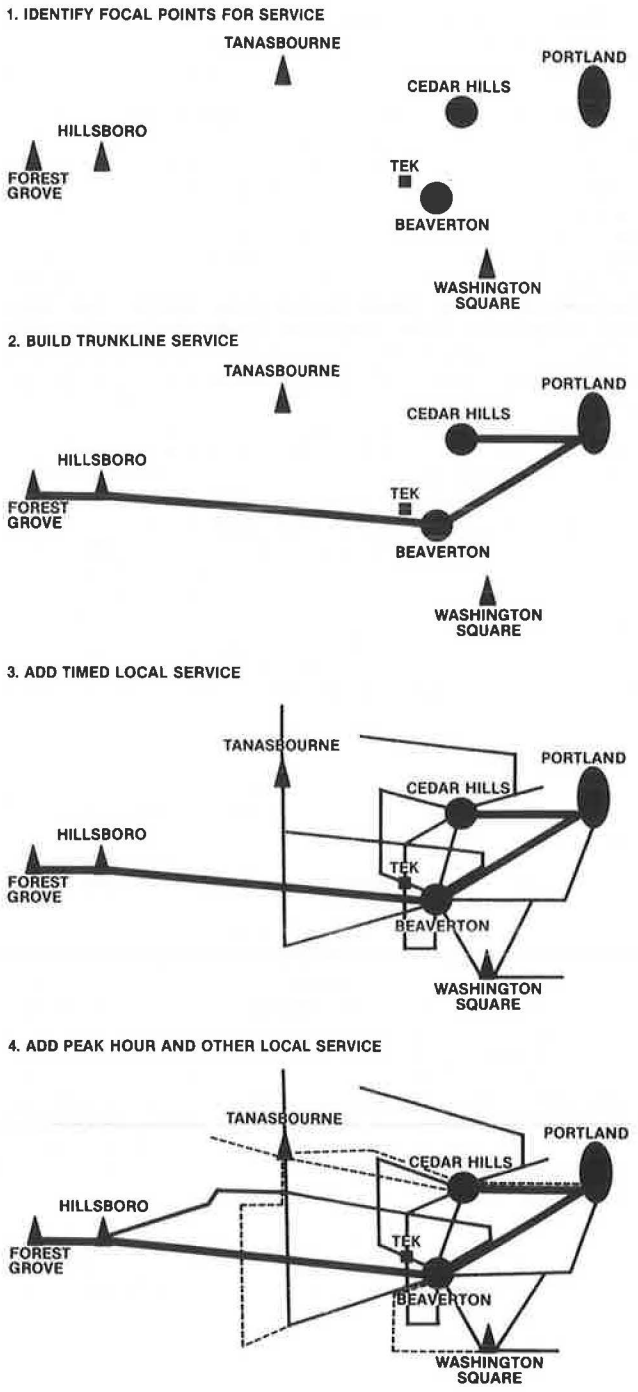
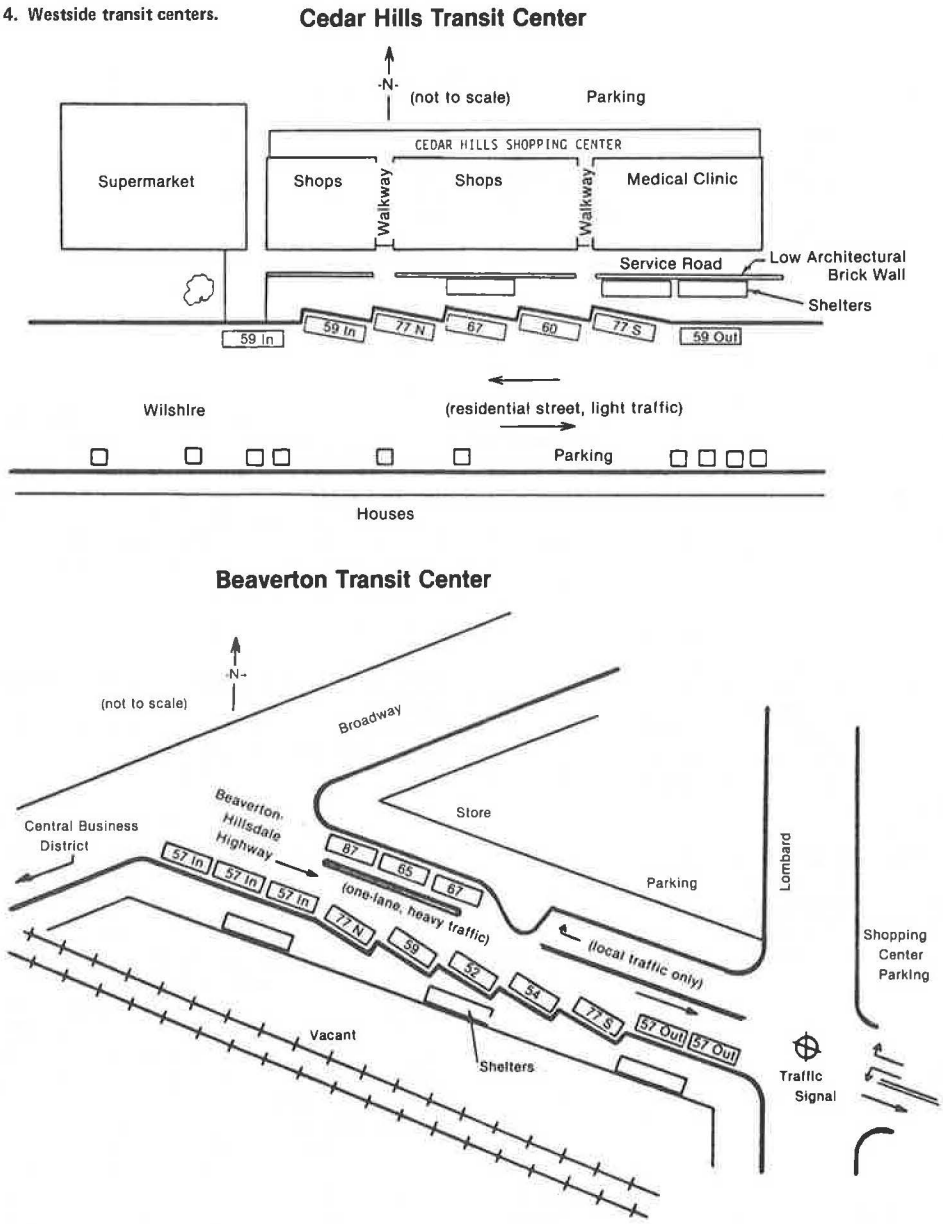


Figure 4. Westside transit centers.



cluded extensive field work and data processing. The evaluation focused on two general areas: service impacts and service reliability. It was designed to determine (a) how well the service had met project objectives and (b) the operational efficiency and effectiveness of the current service design. Where possible, recommendations for improvements were to be made.

Specifically, the study examined three areas of performance:

1. Ridership--Growth and travel patterns,
2. Performance--System and route level, and
3. Schedule reliability.

Performance was related to specific plan objectives and agency-adopted economic performance standards.

The extent to which each of the plan objectives was met, after the first year of operation, is summarized below.

Ridership and Travel Patterns

The Westside service far surpassed year-end ridership goals established for it at implementation. By spring 1980, daily originating ridership on the Westside was 19 286 riders, a 40 percent increase over the spring 1979 total of 13 808 daily riders. This 40 percent increase in ridership is twice the anticipated 20 percent increase set as a goal for spring 1980. In comparison, for the same time period, system originating ridership increased by only 8 percent. If one allows for the 8 percent systemwide increase, it seems reasonable to assume that a significant portion of the additional 32 percent increase in ridership experienced on the Westside can be attributed to new and improved service levels on the Westside resulting from the Westside service plan.

Time-of-day analysis shows that substantial improvements in ridership occurred in both peak and off-peak periods. Off-peak ridership increased 40 percent (>2800 daily trips) over spring 1979 levels. Peak ridership gains resulted in a 38 percent increase (>3050 daily trips) for the same time period (see Table 1).

The Westside plan had a significant, positive

Table 1. Total ridership by time of day: system versus westside.

Time of Day	Spring 1979		Spring 1980		Change				Westside as Percentage of System Change
					No. of Riders		Percent		
	System	Westside	System	Westside	System	Westside	System	Westside	
Peak (7:00-9:00 a.m., 4:00-7:00 p.m.)	67 431	8 148	74 296	11 195	6 865	3047	+10.2	+37.4	44.4
Midday (9:00 a.m.-4:00 p.m.)	60 013	5 782	63 764	8 584	3 751	2802	+6.3	+48.5	74.7
Rest of day	22 455	2 283	27 961	4 634	5 506	2351	+24.5	+103.0	42.7
Total	149 899	16 213	166 021	24 413	16 122	8200	+10.8	+50.6	50.9

Table 2. System economic performance.

Item	Spring 1979		Spring 1980		Spring 1980 (Projected)	
	System	Westside	System	Westside	System	Westside
Operating cost per passenger ($)	0.99	1.20	0.99	1.30	-	1.49
Riders per vehicle hour	26.33	21.69	26.30	20.11	-	17.50

impact on travel patterns. In relative terms, local (intra-Westside) trips and nonwork trips accounted for the largest increase in ridership on the Westside. Local trips increased by an estimated 1100 daily trips, a 138 percent increase over 1977 levels. Analysis of selected origin-destination patterns shows that travel to downtown Portland increased by 1000 daily trips, a 15 percent increase, but that regional trips to downtown increased by only 12 percent. Nonwork trips increased by 68 percent, an additional 2500 daily trips. Thus, the Westside plan has stimulated increased local and nonwork transit tripmaking and also preserved good, attractive service to downtown Portland.

Service Performance

It is important to recognize that, by definition, a timed-transfer network operates as a system of routes, not as a collection of individual lines. The performance of one line depends on the performance of other lines in the system. Therefore, service efficiency and effectiveness were evaluated at both system and route levels.

The Westside service plan required investing a substantial increase in service on the Westside. The table below gives the relevant increases in buses, hours, and miles (miles include deadhead):

Item	Spring 1979	Spring 1980	Increase (%)
Buses	59	86	46
Vehicle hours	636.50	958.85	50
Miles	10 583	14 887	41

Ridership findings indicate that growth in ridership has nearly matched the increase in service provided. Service performance is discussed in detail below.

System Economic Performance

The system economic performance of the Westside service declined slightly in comparison with pre-June 1979 levels. Riders per vehicle hour declined from 21.69 to 20.11, and operating cost per rider increased from $1.20 to $1.30/originating rider. However, both of these statistics for the Westside system are above the levels expected after the first year of operation of the new service (see Table 2).

Schedule Efficiency

Schedule efficiency, as measured by the ratio of revenue service hours to total platform hours, improved with respect to pre-June 1979 levels for the Westside system and with respect to the system as a whole. While the rest of the system experienced a small decrease (75-74 percent) in schedule efficiency between 1979 and 1980, the new Westside service resulted in improved schedule efficiency (73-77 percent) for routes serving that area.

Individual Route Performance

With one exception, individual route performance surpassed minimum economic performance standards (boarding riders per service hour and system cost per passenger). The one exception was a local route (line 68) that serves a developing but still low-density suburban area. Significantly, this route is not connected to either one of the two timed-transfer centers. Based on this analysis, two subsequent actions were taken with respect to this route:

1. In September 1980, a service-level adjustment was implemented. Selected trips were eliminated on line 68. Platform hours were reduced by 17 percent, which had only minimal impact on ridership. Despite a reduction in overall service, the new schedule improved transfer connections to downtown Portland and to Westside community colleges. Projected performance (13.8 riders/vehicle-h) was above the standard for grid and feeder lines (12 riders/vehicle-h).
2. Despite adjustments made to service on line 68, as described above, low ridership levels continued throughout the following year. Tri-Met elected to discontinue service along the route effective September 1981.

Timed-Transfer Schedule Reliability

Implicit in the service design and concept was the assumption that timed transfers would reliably occur as scheduled at the transit centers. The Beaverton and Cedar Hills transit centers provide the physical focus of the Westside timed-transfer system. The following table gives passenger activity at these two transit centers:

Transit Center	Time of Day	Persons	Persons per Hour	Daily Use (%)
Beaverton	Morning peak	2190	880	30
	Midday	2200	315	31
	Evening peak	2160	870	30
	Rest of day	650	--	9
Total		7200	450	100
Cedar Hills	Morning peak	840	340	28
	Midday	1020	146	36
	Evening peak	745	300	25
	Rest of day	315	--	11
Total		2900	180	100

During an average weekday, more than 10 000 people pass through or transfer at the transit centers, 7200 at Beaverton and 2900 at Cedar Hills. Each weekday 28 "meets" occur every 20 min during peak hours and every 30 min in the off-peak. Weekend service meets every 60 min on both Saturday and Sunday. Less frequent service on weekends means longer waits for passengers missing connections than during the weekday, which makes weekend reliability especially critical.

Transfer reliability at each transit center is summarized below:

	Beaverton		Cedar Hills	
Service Day	Meets (%)	Connections (%)	Meets (%)	Connections (%)
Weekday	75	98	93	98
Saturday	76	92	100	100
Sunday	25	81	100	100

Reliability is expressed in two ways: (a) A successful meet is defined as all buses arriving as scheduled at a given time, and (b) a successful connection is defined as a direct transfer connection that results from two routes arriving as scheduled.

The results from the reliability study clearly indicated the need for schedule adjustments to improve meet reliability, especially at the Beaverton transit center. Analysis of the data identified the major problem to be missed connections between outbound (from downtown Portland) trunk-line service and local routes. Transfer reliability between local routes was not identified as a problem, since 98-100 percent of the connections occurred as scheduled. To improve the reliability of transfer between trunk-line routes and local routes, two actions were taken:

1. Heavier than anticipated passenger activity and traffic congestion between downtown Portland and Beaverton-Cedar Hills required increases in running time on the outbound trunk-line service (line 57, Forest Grove, and line 59, Cedar Hills). During weekday service, this meant using evening peak running times earlier in the afternoon on both routes. Saturday running times were increased on line 57 throughout the entire day. Sunday reliability on line 57 was improved by the addition of a bus leaving downtown Portland 10 min ahead of the regularly scheduled service and traveling as far as Beaverton to alleviate the running-time delays due to heavy passenger on-off activity on the trip scheduled to make the meet in Beaverton.
2. A second measure was implemented to improve the reliability of meets by allowing lines 57 and 59 more time for unforeseen delays. This was accomplished by changing the relation between the trunk and local arrival and departure times at the transit centers. Since September 1980, lines 57 and 59 now arrive 3-4 min after the locals, lay over for 3 min during the peak and 2 min in the off-peak, and depart 3 min before the locals. Previously, the trunk routes were scheduled to arrive the last 3 or 4 min of the direct meet and then all the lines left together. Under the new schedule, lines 57 and 59 can be up to 5 min late and still arrive in time to make all scheduled connections.

The net result of the changes described above was to eliminate all of the problems encountered at Cedar Hills transit center on those days observed. At the Beaverton transit center, 29 out of the 114 observed weekday meets were missed. Under the new schedule, an estimated 15 of those 29 misses would have been successfully completed, which improved meet reliability to an estimated 87 percent.

Saturday performance at Beaverton also improved. Under the new schedule, three of the four missed meets would have been successfully completed, which increases Saturday reliability to 94 percent. The impact of the additional service on Sunday performance alleviated heavy passenger loadings on the outbound line 57, which allowed it to make the meet as scheduled.

SUMMARY AND CONCLUSIONS

The Westside timed-transfer service, by nearly all measures, can be judged a success. Ridership has increased at a rate greater than expected, and new travel markets have been attracted to transit use. It is also apparent that the economies of scale inherent in the Westside service design are being realized. Before the timed-transfer service was implemented, capacity was exceeded on many key links in the system, particularly to downtown Portland. Given the previous service pattern, expansion of service was only possible with expensive additions in equipment along the entire length of a route from the suburbs to downtown Portland. Today, however, because of investment in a larger Westside system capable of serving new destinations, and with the flexibility inherent in the timed-transfer concept, there is capacity to handle significant increases in ridership without the addition of new service to local lines.

Since implementation of the timed-transfer concept in the Westside in 1979, similar systems have been placed in operation in two other suburban areas of the Tri-Met service district. One other timed-transfer system is scheduled for implementation in 1983. The concept has proved an effective way to meet the changing travel needs of Portland area residents.

However, it should be emphasized that the timed-transfer concept must be carefully applied and that each application will have unique characteristics to be accounted for in the service design process. The performance of each link of the service depends on the extent to which the service design process recognizes the functional relations that exist between each element of the timed-transfer system. Route planning and schedule design must occur jointly in the development of a timed-transfer system. Route lengths must be directly tied to running-time modules so that maximum schedule reliability and efficiency can be achieved. Once the concept is implemented, careful performance monitoring is required to ensure that necessary adjustments to the service are made in order to guarantee reliable transfer connections at the transit centers. The success of the Westside timed-transfer service has demonstrated that, if applied properly, the timed-transfer concept can, in fact, provide a greater level of service, to more travel markets, more cost effectively than could be achieved through further investments in a radial transit system.

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