CASE STUDY
DOWNTOWN SEATTLE TRANSIT PROJECT

CENTER FOR TRANSPORTATION STUDIES

UNIVERSITY OF MINNESOTA

SEPTEMBER, 1988

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DOWNTOWN SEATTLE TRANSIT PROJECT

SUMMARY

The Seattle metropolitan area consists of over 2,100 square miles and 1.2 million people. The regional public transportation system includes an 1,100 vehicle transit system, 36 miles of High Occupancy Vehicle (HOV) lanes and over 50 park and ride lots with over 11,000 parking spaces. The transportation system has been expanding significantly in recent years as the area population and employment has grown rapidly.

Seattle's primary downtown transportation problem is peak period bus congestion. Six hundred transit vehicles pass through the downtown during peak hours. By 1990, it is anticipated that it would take 20-25 minutes for a bus to pass through the downtown at an average speed of 3-1/2 mph. The buses compete with 180,000 cars which come into the CBD every day. Buses typically operate on a skip stop strategy with 3 coaches in a zone at one time. Buses have a serious problem getting in and out of bus stops and there is a problem with overcrowding at shelters. These conditions led to the Downtown Seattle Transit Project.

The Downtown Seattle Transit Project is a $412 million construction project undertaken by Seattle Metro, which centers on a 1.3 mile-long tunnel under downtown Seattle. This tunnel will be the backbone of a new downtown transportation distribution system connecting directly to Interstate 5. Seattle is shaped roughly like an hourglass with Lake Washington on the east and Puget Sound on the west. The tunnel runs north-south through the middle of the "hourglass", on Third Avenue, and then takes a right angle turn on Pine Street over to a station near I-5. The tunnel will have five stations, three of them underground and one at either end of the tunnel to be used as staging and loading areas. The tunnel will accommodate up to 290 buses (total of both directions) carrying 18,000 passengers during each peak hour by the year 2000. The buses using the tunnel will be dual-powered diesel-electric buses designed by Breda of Italy. The buses are essentially a conventional articulated bus with the center axle driven by electricity from an overhead trolley wire, and the rear axle powered with a conventional diesel engine. The dual-powered buses will be operated in diesel mode in outlying suburban areas and along freeways entering the CBD, and then will switch to overhead electric power.

The principal benefits of the bus tunnel include reducing the travel time for bus riders through downtown by approximately 7 minutes (about 28 percent), improving schedule reliability and reducing bus energy and operating costs. The travel time savings for the average bus rider to the center of downtown attributed to the tunnel is less than the savings for through riders. The tunnel will relieve traffic bottlenecking in downtown Seattle and

will provide needed system capacity through the year 2010. The tunnel is also being designed to accommodate light rail transit in the future as cross-sections, curvature, grade and clearances will handle a wide range of vehicles.

The analysis of downtown transit alternatives began in 1981 when four major alternatives were identified through the scoping process. Initially, the alternatives included 1) do nothing, 2) low cost improvements, 3) transit/pedestrian mall, and 4) transit/pedestrian mall plus transit centers. Underground facilities and new technologies were to be addressed in future studies. However, the project scope was expanded in March, 1983 to include consideration of dual-powered buses and a transit tunnel because the early alternatives were not well-received by the downtown community. The tunnel alternative was soon identified as the only alternative to adequately address both urban design/development and transit operations issues. Support for the concept grew quickly and the tunnel alternative was selected as the preferred option through the EIS process. Construction of the tunnel began in July, 1986 with most activities to be completed at the end of 1989. Transit service is expected to begin on September 1, 1990.

This report presents an overview of the transportation system improvements under construction in Downtown Seattle. The Center for Transportation Studies was assisted by Strgar-Roscoe-Fausch, Inc. in collecting information for this report. The purpose of the report is to provide an analysis of one of the options available to help reduce CBD congestion in major cities throughout the country.

OVERVIEW OF EXISTING CONDITIONS

Transportation Environment

The Seattle and King County area is making significant investments to improve the regional transportation system. The Seattle Metropolitan Council, known as Metro, is a municipal corporation responsible for water quality and public transportation programs in King County. The existing transit system operated by Metro consists of over 200 routes providing service to 1.3 million people over 2,128 square miles. The transit system elements include a 1,100 vehicle fleet consisting primarily of standard and articulated diesel buses and some electric trolley buses (about 100 standard trolley coaches and 45 articulated trolley coaches). Metro was one of this country's first transit systems to use articulated buses and its articulated fleet now is in excess of 400 vehicles. There are more than 50 park-and-ride lots in the service area containing space for over 11,000 vehicles. 1984 ridership was 66 million with about 45 percent headed to the downtown area.

Metro and the Washington State Department of Transportation, WSDOT, have worked together to develop a system of High Occupancy Vehicle (HOV) lanes along area freeways. In 1987 there were 36 directional lane-miles within the HOV system, distributed as follows:

- I-5 North Segment 1: 3.48 miles of one reversible lane within a 3-lane reversible roadway
- I-5 North Segment 2: 2.00 miles of one reversible lane; 4.29 miles northbound lane; 5.84 miles southbound lane
- I-405 Beltway: 6.19 miles northbound lane; 6.19 miles southbound lane
- I-90 Interim HOV: 1.50 miles of one reversible lane
- State Road 520: 2.79 miles westbound only from I-405 to Floating Bridge
- State Road 522: 3.72 miles southbound only for buses only along arterial street

The oldest HOV lane in the system is the 3.5 mile reversible lane along I-5 which opened in the early 1970s. Initially, only buses could use the lane but now the users include carpools. Both I-5 HOV segments require carpools to have 3 or more persons. The separate lanes are on the inside of the roadway. Most on-ramps have HOV bypasses. The I-405 HOV lanes are located on the outside of the roadway and the carpools are defined as 2 or more persons. State Road 520 is one of two east-west routes that cross Lake Washington connecting Seattle to cities east of the lake including Bellevue. The lake crossing includes a one-mile long floating bridge. The westbound HOV lane was created from the outside shoulder of the roadway. The lane started as bus only but now includes carpools with 3 or more persons. This lane operates 24 hours per day. The State Road 522 HOV segment is reserved for buses only along this arterial street.

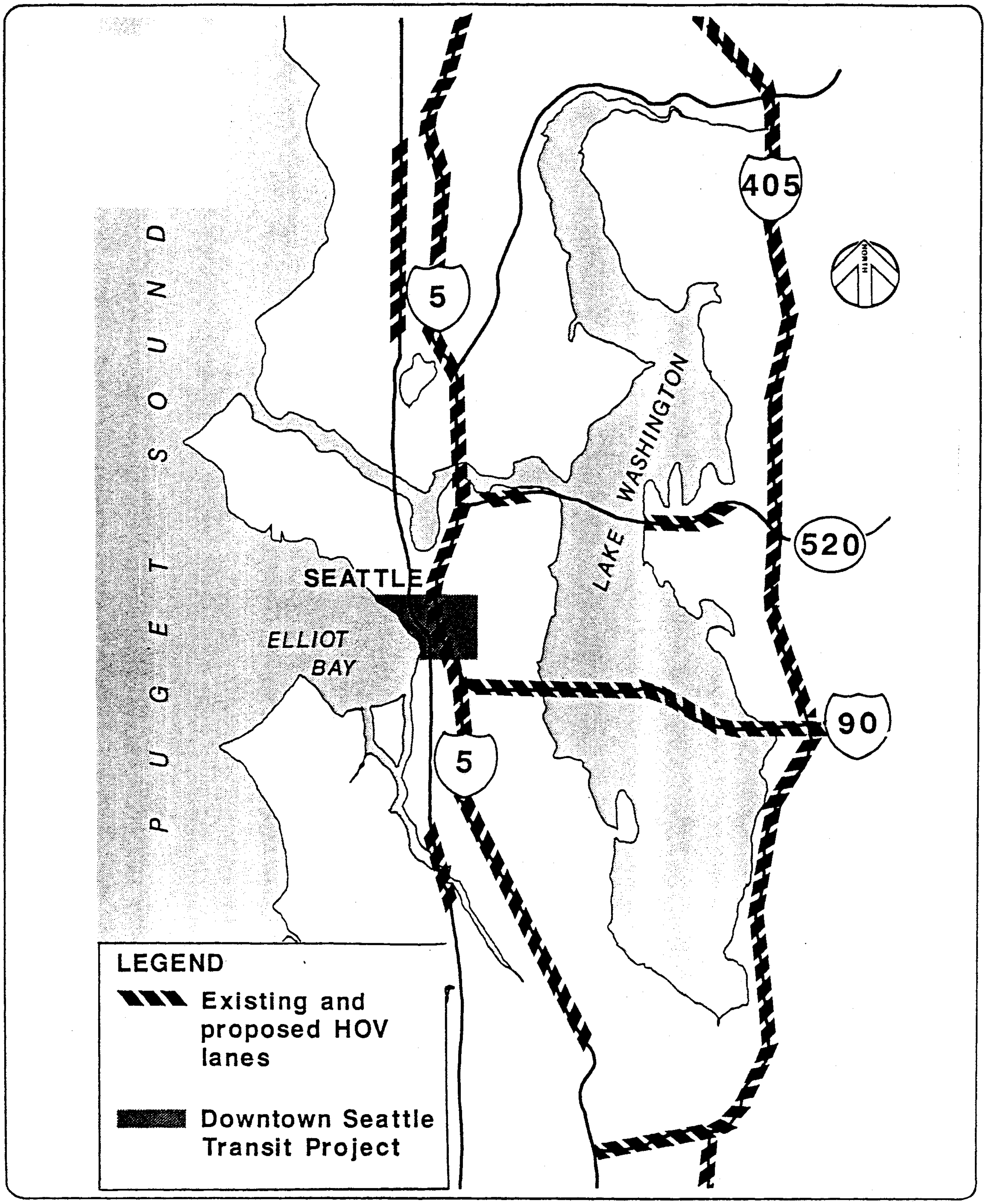
The overall approach to maximizing the movement of people in the Seattle area includes the use of ramp metering on 23 freeway on-ramps, transit stations on freeways for express buses and the HOV lanes. The overall HOV network of 96 lane-miles within King and Snohomish Counties is projected to be completed by 1993. WSDOT has funded the entire cost of construction of the HOV system, which thus far has required an investment of over $400 million.

WSDOT is also involved in a major regional transportation improvement project along Interstate 90. The $1.3 billion project consists of a three-level tunnel through Mount Baker which includes a separate level for buses and carpools, additional transit lanes on the floating bridge on Lake Washington, and the completion of freeway ramps connecting I-5 and I-90 with a busway to downtown. The I-90 project began in 1982 and should be completed by late 1992 or early 1993. The reversible HOV segment will be 4.8 miles long when completed. Figure 1 identifies most of the regional HOV transportation system.

Area Growth

The metro service area covers 2,128 square miles. The 1980 population was 1.2 million, up from 1.1 million in 1970. The City of Seattle comprises 91.6 square miles and its 1980 population was 494,000, down 7 percent from 1970.

Downtown Seattle is the primary commercial center of the Puget Sound region. Downtown contains 13 percent of the total regional jobs and 20 percent of the jobs within King County. Between 70 and 75 percent of downtown jobs are office related. Office space has expanded significantly in recent years, rising from 10 million square feet in 1960 to 23.6 million square feet in 1982.



Seattle Regional Transportation System

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Figure 1

The rapid expansion appears to have peaked, but moderate expansion is expected to persist through 1990. Downtown employment is expected to rise to 146,000 by 1990 from the 1982 level of 127,000.

In 1980, there were 480,000 person trips generated daily in the downtown area. About 114,000 of these trips used transit.

Work trips accounted for about 36 percent of total person trips in 1980. The transit mode split for work trips to downtown has grown significantly in recent years from 31 percent in 1960, to 35 percent in 1975, to 41 percent in 1980.

The auto occupancy for work trips was 1.30 and for all trips was 1.46.

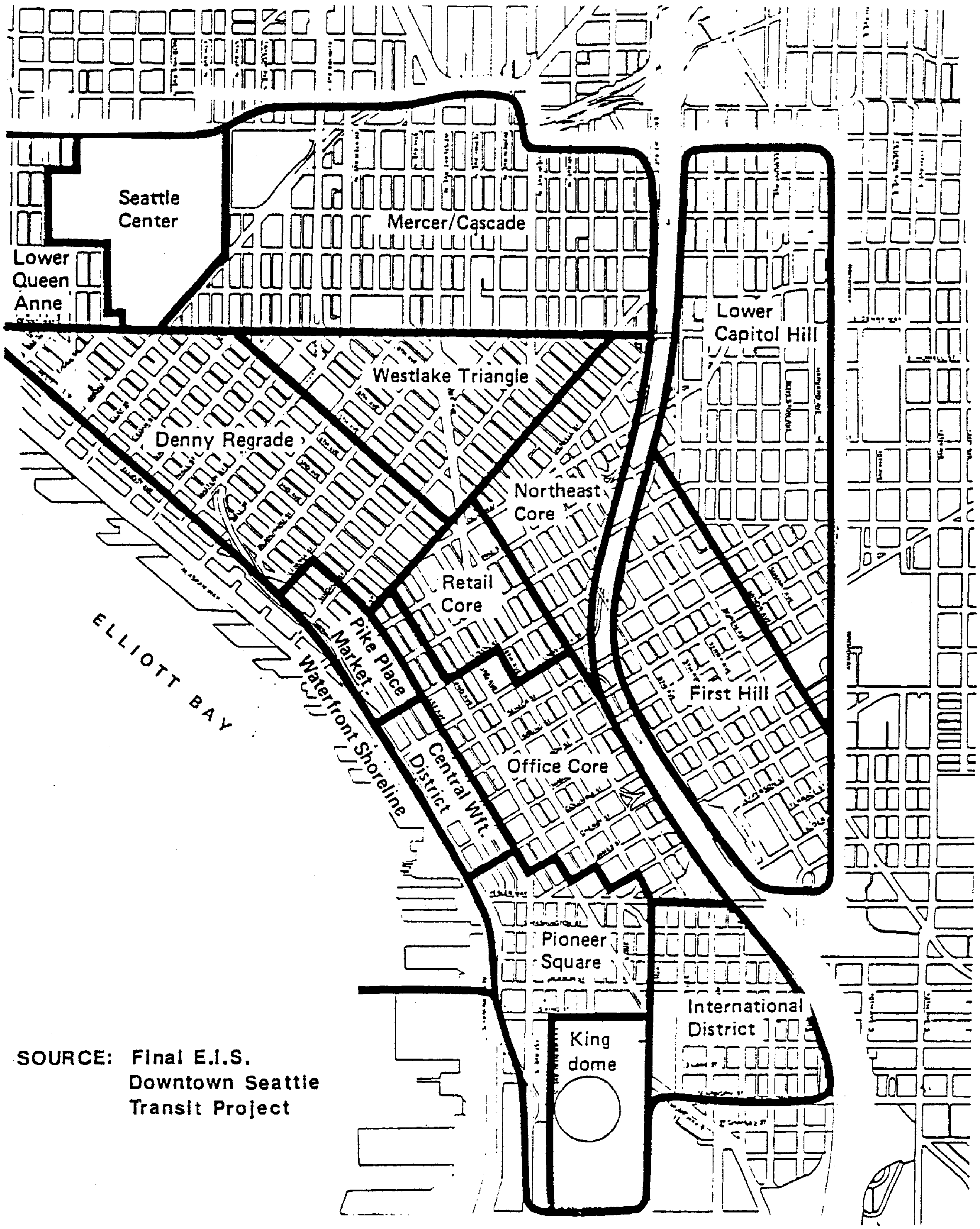
The regional travel demand is expected to continue to grow strongly. By 1990, the peak hour vehicle trip demand is expected to be 28,100, a 16 percent increase over 1980. The auto occupancy rates are expected to rise slightly to 1.35 for work trips and 1.50 for all trips. Without capacity improvements, average vehicle speeds would decline to 7.9 mph during the PM peak hour from the current level of 12.1 mph. Without transit improvements, average bus speeds would decline from 5 mph to 3.5 mph.

Downtown Characteristics

The downtown Seattle transportation network is being expanded significantly to meet the area's expected short-and mid-term travel needs. The existing network is greatly limited by the area's topography. Elliott Bay of Puget Sound on the west and Interstate 5 on the east limit north-south travel within the Central Business District (CBD) to only a few streets. East-west travel is sometimes constrained by steep grades because Seattle is built on a hillside which gradually slopes from east to west. The grades reach 18 percent in some downtown areas.

The CBD is comprised of the following general areas (see Figure 2):

- International District - housing, retail, commercial
- Pioneer Square - offices, retail, residential, original CBD
- Office Core - government, financial, retail offices
- Retail Core - over 3.5 million square feet of retail
- Northeast Core - parking lots, low scale buildings
- Westlake Triangle - commercial uses
- Denny Regrade - mixed use area, new housing
- Pike Place Market - mixed use area, historic
- Central Waterfront - rehabilitated residential, office, hotel, retail
- Waterfront Shoreline - recreation, tourist



SOURCE: Final E.I.S. Downtown Seattle Transit Project

Seattle C.B.D.

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Figure 2

There are about 42,000 parking spaces in downtown Seattle. Eighty-five percent are located in off-street facilities and overall occupancy runs about 82 percent.

There is about 7.6 million square feet of downtown retail space with the major Pine Street department stores comprising nearly 25 percent of the total space. In a recent survey, nearly 90 percent of CBD workers indicated that they have shopped downtown recently during or after work.

The downtown street system capacity began to break down in the early 1980s. Overall intersection level of service (LOS) was generally acceptable, but the LOS for bus operations was quite poor due to queuing at bus stops and conflicts with general traffic and pedestrians. Without capacity improvements, seven major downtown intersections would have LOS D or worse in 1990 compared to three intersections currently at these levels.

Pedestrian volumes are very high near the retail core area, with several blocks being at or over walkway capacities. Sidewalk pedestrian flows are interrupted along several blocks by bus shelters and people waiting to board buses.

The existing downtown air quality is generally good. By 1990, the CBD should meet all air quality standards because overall emissions will be substantially lower than current levels. Existing sound levels generally exceed noise criteria. By 1990, sound levels would rise an additional 2 dBA, which is a barely perceptible change.

THE DOWNTOWN TRANSPORTATION PLAN

The Downtown Seattle Transit Project began in March 1981 as a study initiated by Seattle Metro. The purpose of the study was to form a plan for future transit in downtown Seattle. Without such a plan the downtown transit components were envisioned to decline as reserve capacity would be used up, operating speeds would continue to decline, peak hour congestion would continue to increase, pedestrian conflicts would increase at major bus stops and additional noise and odor problems would occur as the volume of buses increased. Therefore, the study sought to alleviate these problems by finding a transit alternative to meet the following project objectives:

- Provide adequate transit capacity to accommodate future ridership.
- Provide adequate waiting and sidewalk space for downtown transit riders and pedestrians.
- Provide internal circulation within downtown.
- Reduce noise and air quality impacts downtown.

Evaluation of Alternatives

The study evaluated several mid-range (early 1990s) and long-range (2000) transit options. The mid-range general alternatives were:

- No Action: Expand the transit service within the limits of existing street capacity.
- Small Capital Improvements: Provide additional exclusive transit lanes, revise freeway ramps and add a downtown circulation system without major capital investments.
- Transit Mall: Develop dedicated transit and pedestrian streets.
- Transit Mall with Transit Centers: Develop a dedicated transit street with transit transfer facilities (centers).

The long-range considerations included:

- Tunnel Alignment: Determine the feasibility of tunnel construction.
- Dual Propulsion Technology: Evaluate conversion of buses to operate under dual-power technology.

- Corridor Study: Identify high capacity routes that might be well-served by a different technology (such as light rail transit).

The formal Environmental Impact Study (EIS) process began in December 1981 with a scoping hearing to review the following alternatives:

1. No Action

2. Transportation System Management
   - TSM Mall
   - Dual contraflow lanes

3. Non-Intercept Mall (TSM)

4. Mall with Transit Centers
   - Peripheral terminals
   - Peripheral stations
   - Close-in terminals
   - Close-in stations

Alternative 1, No Action, used 1990 as the horizon year. None of the project objectives would have been met with this alternative. Alternatives 2 and 3, the TSM options, attempted to meet project objectives with limited capital investments and traffic management. The TSM Mall would have operated along Third Avenue with two transit-only lanes per direction. The TSM Dual Contraflow lanes would have operated along Second and Fourth Avenues (for southbound and northbound buses, respectively). The Non-intercept Mall alternative would have used a bus-only mall along Third Avenue in conjunction with dual-powered buses to minimize noise and air quality impacts, and the addition of significant passenger amenities and increased sidewalk widths at waiting shelters. Alternative 4, the Mall with Transit Centers alternatives, would have used transit centers in conjunction with a Third Avenue transit mall. Regional transit passengers would transfer to high capacity electric trolley buses at the transit centers for distribution throughout the core of the CBD. Terminals were considered large scale and would have intercepted about 48 percent of all peak hour buses approaching downtown. Stations were smaller scale and would have intercepted 29 percent of peak hour buses.

The project scope was expanded in March, 1983 as a new alternative was added to the analysis. A transit tunnel option using dual-powered buses along Third Avenue and Pine Street, or Fourth Avenue and Pine Street, was added since none of the original four alternatives was found to meet the objectives of the downtown community nor transit agency. The mall alternatives were initially identified as cost-effective solutions, but there was little local support for these options as businesses were not interested in supporting the mall. Metro became instrumental in getting the tunnel alternative selected as significant local support for the option was gathered. The cost of the tunnel was significantly higher than all other alternatives, but the transit travel time savings were also significantly higher than with the other alternatives. The prospects appeared good to receive favorable federal reaction to the alternative since travel time savings was a key Urban Mass Transportation Administration (UMTA) evaluation criterion. The analysis of the tunnel alternative was quickly brought to the level of the other alternatives and by November, 1983 this was chosen as the preferred alternative.

The tunnel alternative offered the opportunity to continue the Seattle area commitment to the "one-seat ride". This concept suggests that point-to-point direct travel is very important in the area and that transfers will be minimized. This strong commitment to the one-seat ride was evidenced in the analysis of the mall with shuttle alternatives. Those alternatives received little suburban support for switching modes and standing for the last portion of their trip.

The draft EIS for the transit tunnel was completed March 1984. A $6.1 million preliminary engineering contract was executed May 1984 and completed in May 1985. The final EIS was completed June 1985. The final design process began Fall 1985, construction began 1986, and operations are expected to begin 1990.

Cost and Funding

Construction of the Downtown Seattle Transit Project, consisting of tunnel and stations, surface street improvements and downtown circulator system, will cost $426.3 million. The tunnel and station elements alone will cost $397.2 million. The cost of the project will be split 50/50 by the Federal Urban Mass Transportation Administration and the local area. Local funds are generated from a portion of the 8.1 percent general retail sales tax. (There is no state income tax in Washington.) Metro's share is 0.6 percent of the sales tax, with one-third being set aside for capital projects. Construction funding includes the issuance of long-term debt bonds backed by the local sales tax. A local improvement district was also established and businesses will make a $20 million contribution to the project. Assessments will include a "a latecomer feature". $13 million will be assessed when the tunnel is opened and $7 million will be assessed 10 years later. The 1986 cost of the 236 dual-powered buses, awarded on a bid basis to Breda, was $429,780 per vehicle. The addition of sales tax, a contingency fund for inflation, two tunnel tow trucks, consulting fees, radios, special tools, passenger counters and staff labor will bring the total fleet cost to $137.9 million.

TUNNEL

The electric-only transit tunnel will significantly increase transit operating speeds, improve schedule reliability and reduce sidewalk overcrowding at waiting shelters. In conjunction with the tunnel, surface street improvements and an enhanced circulation system are to be implemented. The 1.3 mile L-shaped tunnel under Third Avenue and Pine Street includes five passenger stations and will be capable of handling 9,000 passengers in each direction during the peak hour. The tunnel option was determined to have the longest life before reaching capacity (about 20 years), the highest operating savings versus No Action ($4.4 million per year in 1990), and provided the highest travel time savings through the CBD (7.0 minutes per vehicle trip through the CBD). This alternative was also the most costly considered (about 50 percent more costly than the Transit Mall with peripheral stations or terminals, about 5-10 percent more costly than the Mall with close-in stations or terminals). The transit tunnel is being constructed to ensure possible conversion for future rail use. Elements considered during design include platform length, horizontal and vertical curve radii, tunnel diameter, exit requirements and power supply requirements.

Construction of the tunnel is to occur mostly within the street right-of-way. Some right-of-way and easements are required for the stations. Figure 3 shows the general alignment. The tunnel is connected to I-5 on the south by exit ramps from the Thompson Freeway. These previously unconnected ramps will be connected to the bus tunnel under a freeway access called Airport Way. The tunnel passes under the existing Burlington Northern Railroad tunnel near the south end of the project.

The tunnel is being bored from the south end along Third Avenue. Two 21 foot 3 inch "cookie cutter" tubes are being cut up to Pine Street. The Pine Street section is a cut and cover concrete box segment. In the station areas, the tubes open into a three lane section with passenger loading platforms. Tunnel walls are being formed primarily with precast tunnel liners. Conventional construction methods are being used as the ground has been fairly dry to cut through.

There is some question concerning whether or not to lay the rails for LRT in the tunnel at this time as a symbolic commitment to Light Rail and to avoid disruption at some later point if LRT is implemented. The local problem with LRT will be which corridor to build first since there are three principal corridors to consider. The tunnel floor is being constructed with slots for rails which can be quickly converted if deemed necessary.

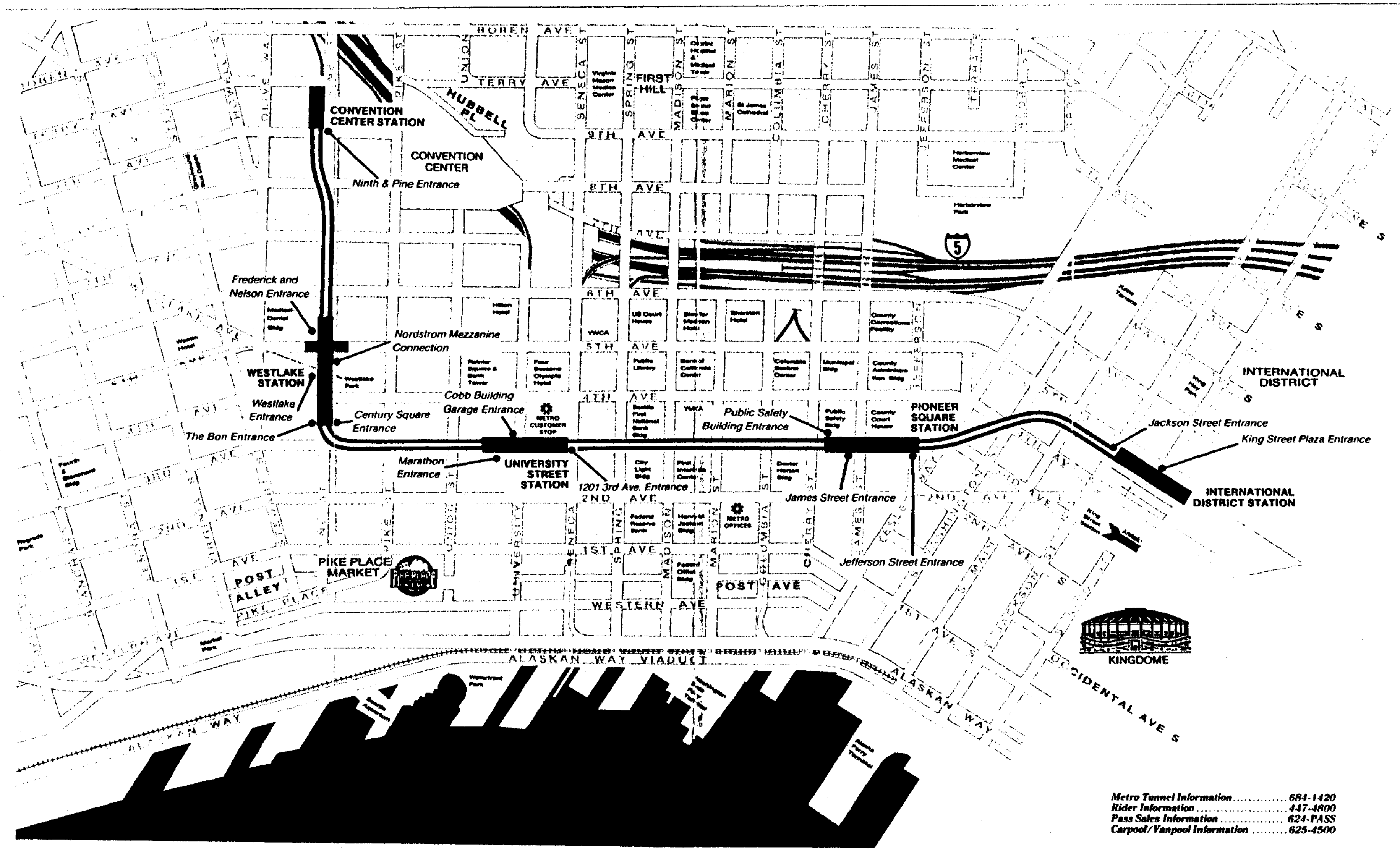

Figure 3

Downtown Seattle Transit Tunnel and Station Layout

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STATIONS

The tunnel alternative includes five passenger stations, three intermediate stations plus one at either end. The five stations will have adequate capacity to accommodate projected transit users. It is estimated that 50 percent of tunnel users will be within a two-block walk of their final destination and 92 percent will be within a three-block walk. Initially, six stations had been considered but the additional station would have cost $40 million extra to construct and up to $600,000 per year to operate.

The International District Station, located at the south entrance to the tunnel, will be adjacent to the Union Station train depot. Buses coming from the south on Interstate 5 and Interstate 90 will use this station. The station design will highlight the international image of the area using Chinese and Japanese artforms. This station is being built on part of an abandoned railroad yard which will ultimately involve a joint air rights project restoring a historical railroad station and building by a real estate arm of the UP Railroad. The station is adjacent to the Burlington Northern station which is the original Great Northern Station built in 1900.

The Pioneer Square Station serves primarily government and office workers with entrances to the Public Safety Building and Lyon Building. The station design will highlight the adjoining historic district by using colored granite walls and arched ceilings, cast iron gates and large clocks on the mezzanine levels.

The University Street Station is located in the heart of the financial district with entrances located in two major private developments. The design will feature polished steel, ceramic wall tiles and electronic images along mezzanine walls. This station will have the highest passenger volumes of the tunnel system.

The Westlake Station is located in the center of the downtown retail core. The station includes a mezzanine of more than one block in length that will act as an underground bridge connecting the major department stores which have mezzanine level entrances. This station is directly below the monorail terminal. The design includes use of ceramic tiles and murals to portray street scenes. This is anticipated to be the second busiest station with peak hour volumes expected to be about 6,000.

The Convention Center Station is an open-air station where buses assemble to form platoons of four for travel through the tunnel. Four northbound passenger platforms and one southbound platform are used.

The International District, Pioneer Square, University Street and Westlake Stations are connected by twin-bored tunnels with approximately a 20 foot outside diameter. Tunnel depth varies between 60 and 70 feet. Factors such as station mezzanines and crossing beneath an existing Burlington Northern railroad tunnel cause the depth to vary. The Westlake to Convention Center Station segment is a single box structure with two traffic lanes. The tunnel roadway widens to three lanes at the stations to provide a passing lane.

Each station includes stairs, escalators and elevators to provide complete accessibility to the system. Mechanical lifts on the buses are used to load wheelchair patrons. Mezzanine level crosswalks connect the loading platforms on each side of the tunnel. Stations will be ventilated, but not heated or cooled. No retail activity is planned at any station as stations will be connected to the major department stores along Third Avenue. Fare collection equipment will not be necessary in the stations because the tunnel is entirely within the downtown free fare zone.

The International District Station and the three intermediate stations utilize curb-height linear boarding platforms on each side of the roadway. The platforms are approximately 380 feet long and 15-1/2 feet wide. Each has four berths for four-bus platoons. Two-bus A and B segments will be designated at the platforms to assist passengers in identifying their bus.

Each of the five tunnel stations will complement its adjoining downtown neighborhood with the aid of a $1.5 million public arts program.

VEHICLES

The preferred alternative specified that only electric-powered vehicles would operate in the transit tunnel. The vehicle selected is a dual-powered vehicle which will operate under diesel power on surface streets and under electric power in the tunnel. The electric power is supplied by overhead wire similar to trolley bus operations.

Dual-mode technology is currently used in several European transit applications. Nancy, France, a city of 300,000 people, has operated dual-powered vehicles since September, 1982. The vehicles operate on electric power along a downtown transit mall and on diesel power in areas where bus volumes do not justify the cost of overhead trolley wires. The 48 vehicles used were manufactured by Renault. Switching from diesel to electric power requires between five and ten seconds. Essen, Germany, a city of about 500,000 people, has operated dual-powered mechanically-guided buses through a downtown streetcar tunnel since April, 1983. The small diameter tunnel with poor ventilation for diesel operations, required development of the dual-powered mechanically-guided vehicles. These vehicles were manufactured by Daimler-Benz and Maschinenfabrik-Augsburg-Nurnberg (MAN). The mechanical guidance design includes guide rollers fitted to either side of the bus forward of the front wheels along with a guide rail. The guide rollers are connected to the steering linkage of the bus. Switching from manual steering to guided steering can occur by simply driving onto a guideway. Additional dual-powered applications are found in Esslingen, Germany and St. Etienne and Grenoble, France.

Dual-powered vehicles have been used previously in the United States. In 1934, the Public Service Coordinated Transport Company of New Jersey tested a gasoline/electric powered vehicle that used a gasoline engine to power an electric generator in areas where overhead electric power was not available. The technology was accepted and dual-powered service operated until 1948, when the fleet became all diesel-powered.

Seattle Metro tested two versions of the dual-powered vehicles, a Renault in 1983 and a Neoplan in 1985. The vehicles were extensively tested for 12 months with special emphasis on on-wire and off-wire operating characteristics including acceleration, hill climbing, passenger loading, vehicle weight, exterior and interior noise and operational safety. The vehicles operated with no serious problems and the technology was given approval for Seattle.

The Breda Company of Florence, Italy was awarded the bid for 236 dual-powered articulated buses with wheelchair lifts. The buses have 325 hp diesel motor capacity and 201 hp electric motor capacity, are 61 feet in length, 8.6 feet wide, 10 feet high, have a passenger capacity of 66 seated, 15 standing and two wheelchairs. The three-axle, articulated vehicles will use a Detroit Allison diesel engine for surface operations. For tunnel operations the buses switch to 700 volt, direct current power collected from overhead trolley wires. Switching can be completed in about 12 seconds. Top speed in diesel operation will be 55 mph and 40 mph in electric operation.

The first four prototype vehicles will arrive for testing in August, 1988. The 232 production vehicles are scheduled for delivery between October 1989 and May 1990. The prototypes will be assembled in Italy and the production vehicles will be assembled in the U.S. By 1995, Seattle Metro intends to purchase approximately 490 dual-powered articulated buses.

The reaction locally to the dual-powered vehicles is not uniform. Some of the neighborhoods want Metro to use the electric mode in neighborhoods to eliminate fumes while some neighborhoods want diesel in order to eliminate the overhead wire catenary system. Some neighborhoods are already familiar with the overhead system through the trolley bus experience.

OPERATING PLAN

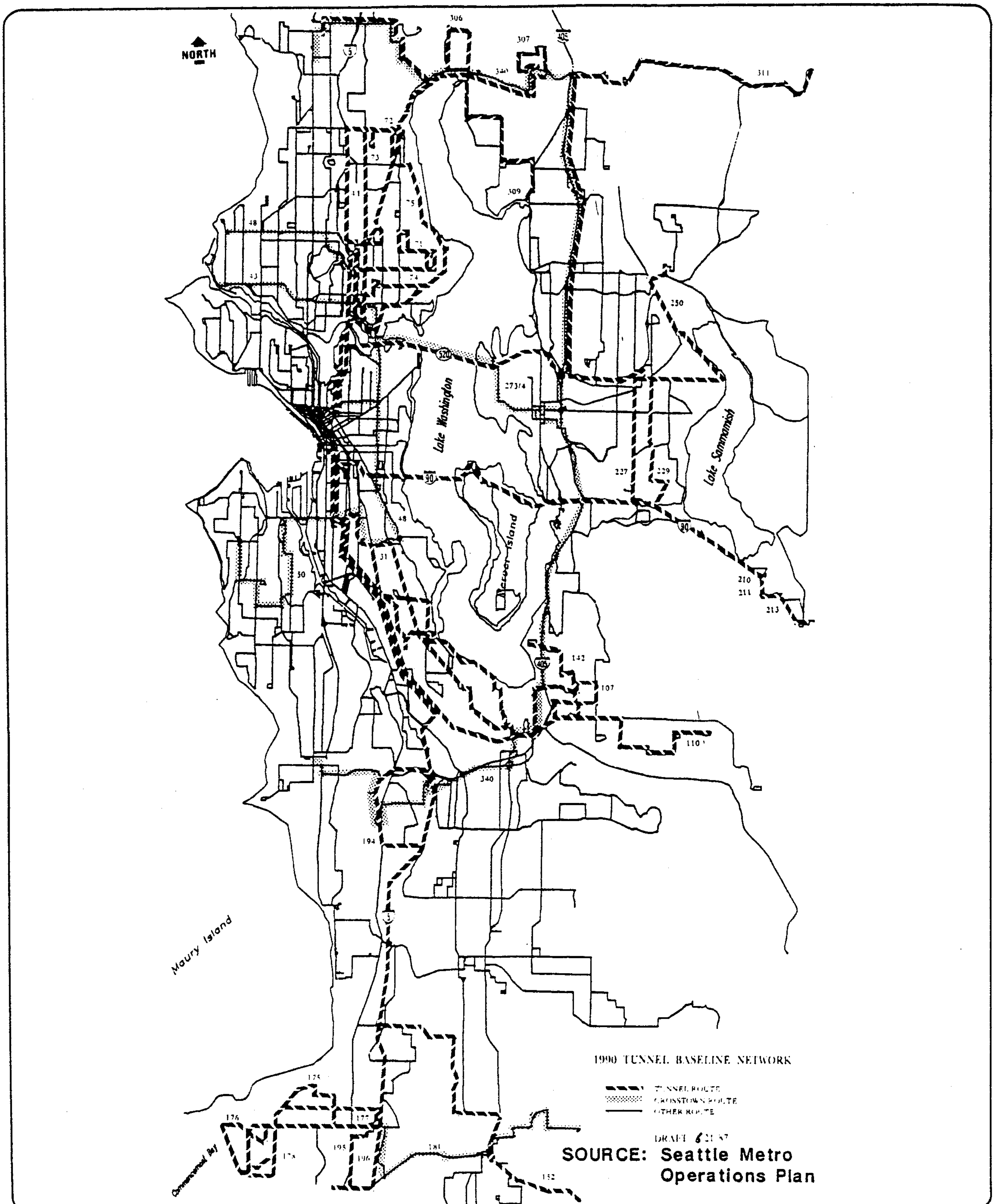
The dual-powered buses will be distributed throughout the metropolitan service area in order to optimize the use of the vehicle and equitably distribute the tunnel benefits. Since all dual-powered vehicles will be articulated, only routes with high passenger load factors and volumes, and/or significant park-and-ride capacity with a feeder network will be considered for tunnel operations. The selection of routes has not been finalized at this time. Either the existing baseline network will be utilized or a new trunk line plus feeder system will be developed (see Figures 4 and 5).

Tunnel transit route selection and volumes will be constrained at start-up by the limited availability of dual-powered vehicles. By 1990, the system will have 236 vehicles and, by 1995, it is expected that about 490 dual-powered vehicles will be in the system. Initially, only 78 percent of the dual-powered fleet will be allocated to routes. A 10 percent general reserve plus a 12 percent maintenance reserve will be retained through the first phase of operations (up to 1993 or 1995).

The ultimate peak hour tunnel volume is anticipated to be between 145 and 180 buses per direction. This will generate a peak hour directional capacity of between 9,400 and 11,700 passenger seats in the articulated vehicles. The year 2000 PM peak hour bus volume forecast is 156 northbound and 148 southbound. The midday volume is expected to be about 43 buses per hour in each direction.

During the peak periods, buses will assemble at the tunnel ends to switch from diesel to electric power and to be formed into bus platoons for travel through the tunnel. The staging area will accommodate up to 35 buses at the same time. Bus platoons will consist of two to a maximum of four vehicles. Platoons will enter the tunnel at approximately 80 second headways during the peak of the peak hour and at about 2 minute headways during the rest of the peak hour. This results in a peak 15 minute volume of about 50 buses in the primary direction. A staging supervisor will release the platoons.

All buses in the platoon will enter and leave the station area as a group. Each bus will have a designated stop area along the loading platform. Platoons are essential for smooth bus operations and for simplifying passenger boarding. Since all vehicles will be wheelchair lift-equipped, platoons will be held at the station during wheelchair patron boarding and alighting. Following platoons will not be allowed to pass at a station but will be held at the station. Significant delays are not expected during these procedures.



1990 Tunnel Baseline Network

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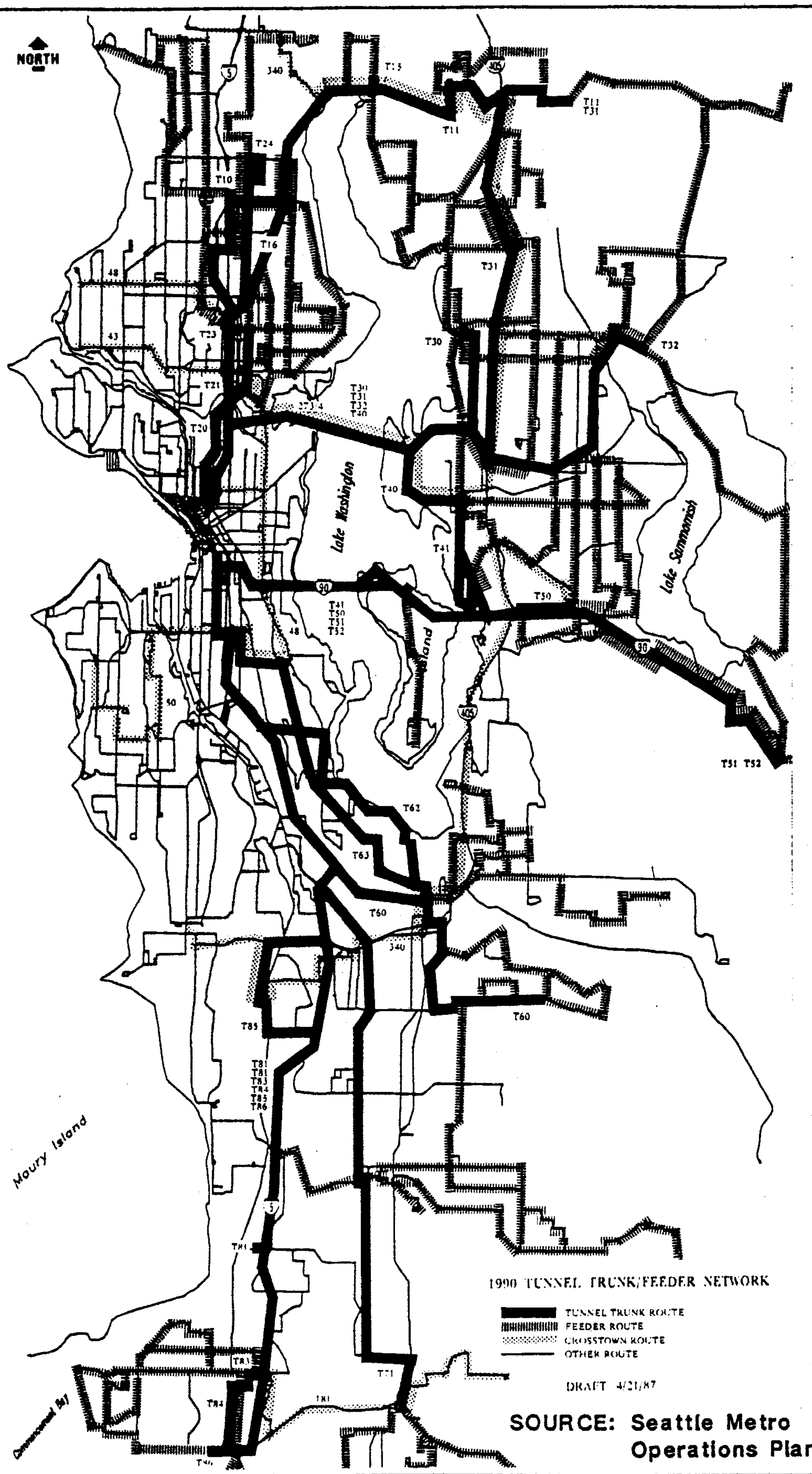
Figure 4



1990 Tunnel Trunk/Feeder Network

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Figure 5

The initial hours of tunnel operation are anticipated to be 5:00 AM through 7:00 PM Monday through Saturday. Nighttime and Sunday bus and passenger volumes can be accommodated on Third Avenue with no congestion-related problems. The projected tunnel and surface bus volumes by time of day are as follows:

	Tunnel		Third Avenue(*)	
	1990	2000	1990	2000
Peak	60	145	80	70
Midday	22	55	52	45
Saturday	22	40	50	45
Night/Sunday	16	30	30	30

(*) With Tunnel

When the tunnel is closed, routes selected for dual-powered vehicles will operate through downtown in trolley mode.

The downtown surface street bus volumes during peak hours would be 656 in 1990 under No Action and 462 with the tunnel. In 2000, the No Action surface volume would be 676 and the surface volume with tunnel would be 386. The significant surface volume decrease is due to additional dual-powered fleet coming on-line.

Tunnel operating speeds are a function of safety and passenger comfort. Superelevation has been included in the curves to achieve acceptable passenger comfort levels. The initial tunnel speed limits are as follows:

Staging Area	15 mph
Curves	20 - 25 mph
Tangent	30 mph
Stations	15 mph
Switches	5 mph

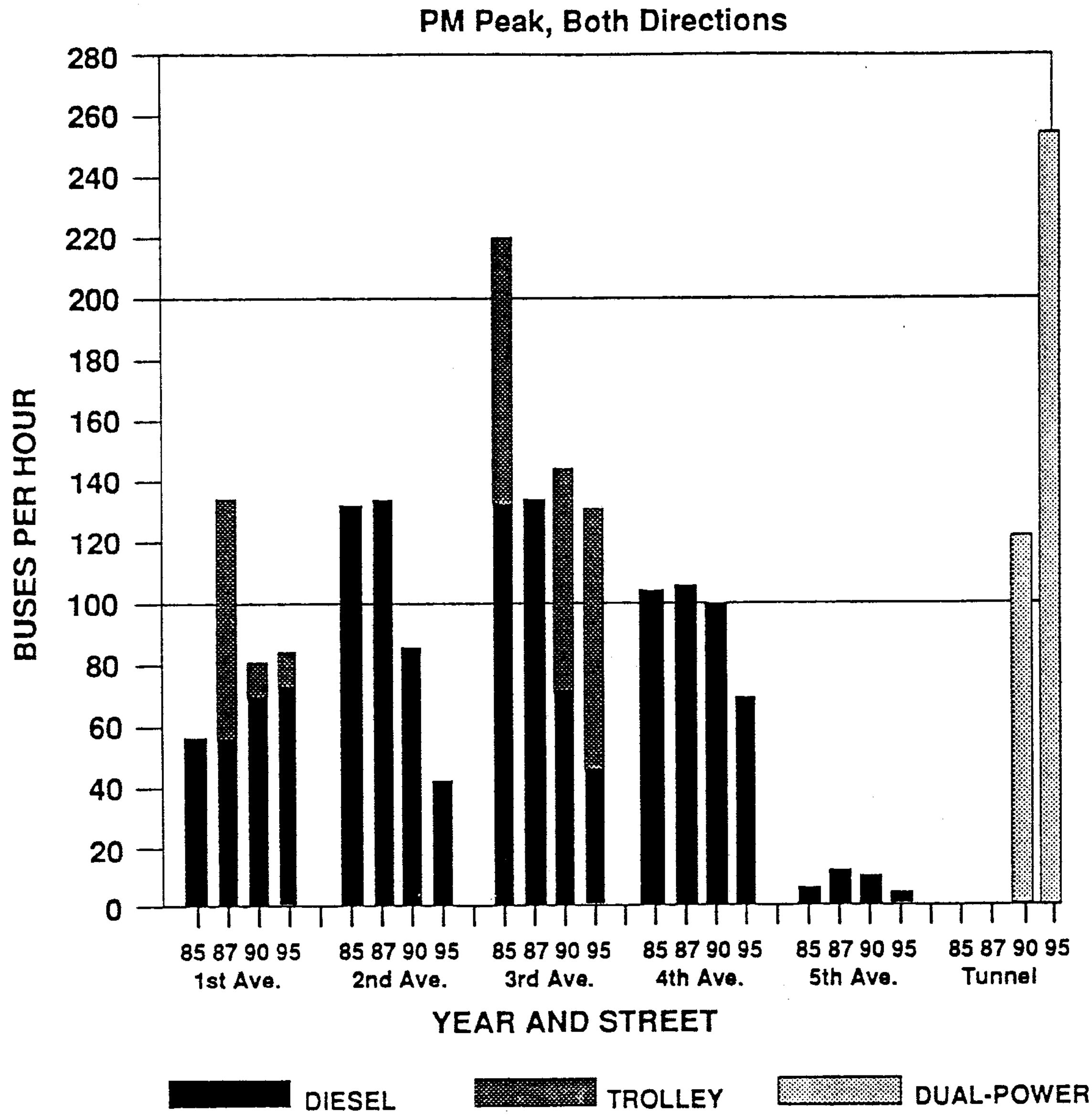
Simulations of tunnel operations with fully loaded vehicles yield estimates of speed and running time as follows:

		1990	2000
Speed (mph)	Peak	11.2	10.5
	Off-Peak	11.8	11.8
Running Time (min.)	Peak	8.8	9.4
	Off-Peak	8.4	8.4

The tunnel will probably be used to accommodate some of Metro's deadhead requirements. Up to 63 trips per hour in the peak, southbound in the AM and northbound in the PM, are possible selections. The tunnel may also be used by non-dual-powered trolley buses operating in the downtown area. Additional study will determine the feasibility and cost of modifying the existing trolleys to accept quick hook-ups for towing in the event of failure. The expected makeup and change in downtown area bus volumes is shown in Figure 6 for the time period of 1985 through 1995.

Transit in the downtown involves a free fare zone where passengers can get on and off the buses at no cost. The downtown system is unique in that it includes the bus tunnel, a surface electric trolley system essentially up and down the hill, the waterfront historic trolley and monorail to the Space Needle. These will all be coordinated in the new plan. There is extensive new development occurring in the northwest corner of the downtown including the development by the Rouse Company which will be the east-most end of the monorail system and will tie into the shuttle.

Essentially, the buses in the tunnel will operate like trains. They will be staged in groups of four and signaled through the tunnel to keep buses in order at the platform. Johnson Controls has developed a control system and is using off-the-shelf hardware much like an LRT system would use. Detection will be by an electric eye system instead of the conventional loops.



SOURCE: Seattle Metro Operations Plan

Seattle C.B.D. Bus Volumes

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Figure 6

RIDERSHIP

The total CBD peak hour transit capacity will become 43,000 riders (including the surface street operations) compared to the No Action capacity of 25,000 riders. The ridership for each alternative studied for the downtown was based on individual travel times and the expected number of transfers required to reach final destinations.

The tunnel alternative would have the largest ridership because it offers the shortest transit travel times with only a small increase in transfers required. The No Action alternative had the lowest ridership.

	1990 CBD Peak Hour Ridership	1990 System Annual Ridership
No Action Alternative	25,000	85.5 Million
Tunnel Alternative	29,300	86.7 Million

Without the tunnel, full utilization of downtown transit reserve capacity would have been reached by the mid-1980s. With the tunnel, sufficient downtown transit capacity is expected to exist beyond 2000. Buses operating on the surface in the downtown are expected to average about 5 mph in the future while buses operating in the tunnel will operate between 11 and 12 mph. The tunnel will reduce the average travel time for transit riders in 1990 by about 28 percent (from 25.3 to 18.3 minutes). The tunnel will require a few riders to make additional transfers to complete their trips. An increase of transfers over No-Action of 9 percent is expected in 1990 for the peak hour.

FINDINGS AND CONCLUSIONS

The Downtown Seattle Transit Project should accommodate downtown transit operations for the next 20 years. The combination of the electric transit tunnel and the dual-powered buses will most likely fulfill the primary project objectives relating to increasing transit capacity and operating speed, and reducing pedestrian and waiting area conflicts.

The decision to construct the tunnel and purchase the dual-powered buses was based on several criteria. The existing transportation network in downtown Seattle is greatly limited by the steep slopes immediately to the east of downtown. This limits transit and mixed traffic operations to a few north-south streets. This constriction in the downtown could not be easily overcome with surface level alternatives.

The level of service for downtown bus operations began to deteriorate significantly in the late 1970s and early 1980s. The primary transit street was Third Avenue and almost all routes through the downtown had to travel along this street. This led to lengthy bus queues and bunching at bus stops, and to sidewalk waiting area conflicts between transit passengers and pedestrians as some downtown sidewalks were quite narrow. Without improvements, it was anticipated that seven major downtown intersections would operate at Level of Service (LOS) D or worse by 1990. This would have resulted in a transit travel time of 20 to 25 minutes through downtown at an average speed of 3-1/2 mph.

The overall level of bus congestion during peak periods, the overcrowding at waiting shelters, the conflicts with general pedestrian traffic and the slow travel time were key concerns of Metro and the downtown business community. As the initial study of alternatives progressed, it became apparent that the surface level alternatives would not be able to satisfy all concerns. The business community was not enthusiastic about any of the options, especially an auto-restricted mall along Third Avenue. Since Third Avenue and Pine Street are the hub of retail sales activities, the transit only mall alternatives were viewed as removing valuable traffic from the area.

The tunnel was quickly identified as the best solution to the downtown transit problems once the idea was proposed. The tunnel provides an opportunity for transit service to quickly travel through the downtown area yet serving the heart of the downtown. Connections to the surface will provide quick access for all users with direct building access available in some locations. The number of stations ensures that the effects of peaking or bunching of users will be minimized. The design of the stations, with wide loading platforms and mezzanine crossovers, will facilitate the rapid movement of large numbers of users. These features will lead to significant travel time savings for Metro and its passengers. The time savings for Metro may result in opportunities to reduce peak fleet requirements as buses may be able to complete additional full period runs. This would result in direct operational cost savings. In addition, Metro will be able to provide downtown service as scheduled since on-time performance should improve. This improved reliability will likely be well received by potential transit users who will quickly learn that they can count on the service. This could lead to increased transit use in the downtown as Metro has forecasted. The tunnel allows the continued operation of Third Avenue as a mixed traffic street, which is seen as a key benefit by the local business community. The primary negative feature is the significant construction cost of the tunnel and stations.

Construction of the tunnel employs fairly common techniques for the bored with precast liners and cut and cover concrete box segments. Other elements of the tunnel, including the stations, also use a fairly standard construction methods and materials. The operations will be controlled by a signal system limited to a central dispatching center. No fare equipment will be necessary in the stations because the tunnel is entirely within the free-fare downtown zone.

The downtown tunnel could have been designed to accommodate standard diesel buses but the venting requirements to the surface would have placed unsightly stacks or vents in the heart of downtown. This venting would have contributed to downtown air pollution instead of helping to alleviate the problem. The limitations of standard trolley buses, particularly for overhead power for freeway operation, were well-known locally. Metro quickly turned to the option of dual-powered buses which could operate in standard diesel mode in outlying suburban areas and along freeways entering the CBD, but then could switch to electric power for operation in the tunnel. These vehicles offer significant flexibility in their operation whereas standard trolley buses are limited to operations where overhead power systems can be provided.

Recent applications of dual-powered bus technology are limited to a few European experiences. Thus far, the technology has functioned well. The greatest disadvantages are the price of the vehicles and the poor acceleration and hill-climbing abilities. The durability of the vehicles and their maintenance level will have to be proven.

In order to minimize the vehicle procurement problems, Metro has developed a multiple-stage bidding process. The first stage was to publish vehicle specifications for the bus they had in mind, and then asked manufacturers for possible improvements. Modifications to the specifications were required since the vehicles could not meet acceleration or hill climbing expectations. Finally, the proposal from Breda had to be carefully reviewed because they used a diesel pusher on the third axle. Factory visits and slalom, braking and high-speed tests were required to convince Metro officials of the performance capabilities. After selection of Breda as the manufacturer, a Metro staffer has been assigned to monitor design and production. Because of the new technology, Metro is paying very close attention to all aspects of the vehicle procurement process.

The funding of the project represents a break from previous federal participation. Under previous UMTA guidelines, the typical federal share of capital expenditures for transit projects was 80 percent with the local share at 20 percent. For this project, Seattle proposed a local share of 50 percent of the project cost which was appealing to UMTA. The local funding includes assessments for businesses who will benefit directly from the project in terms of direct connection to the stations and fronting along the project. It is clear that Seattle understood the process to gain UMTA approval and worked very diligently to get that approval.

Metro has had tremendous coordination with local businessmen. Commitment was made to restore the surface of Pine Street in the retail segment during Christmas season 1986-1987. A commitment was also made that two lanes of traffic would be maintained on Third. This has also been accomplished.