TECHNICAL APPENDIX F

CAPACITY CALCULATIONS

The technical references and capacity calculations for the transportation facilities reflected in the DEIS Executive Summary are as follows:

Freeway General Purpose Lane (GPL)

Capacity, as defined by the 1985 Highway Capacity Manual (HCM), Special Report 209 prepared by the Transportation Research Board, is "the maximum (15-minute) rate of flow at which traffic can pass a point or uniform segment of freeway under prevailing roadway and traffic conditions." It is computed from the following:

$$SF_i = MSF_i \times N \times f_w \times f_{hv} \times f_p$$

where

SF_i = service flow rate for level of service (LOS) i under prevailing roadway and traffic conditions for N lanes in one direction, in vehicles per hour (vph);

MSF_i = maximum service flow rate per lane for LOS i under ideal conditions, in passenger cars per hour per lane (pcphpl);

N = number of lanes in one direction;

f_w = factor to adjust for the effects of restricted lane widths and lateral clearances;

f_{hv} = factor to adjust for the effect of heavy vehicles in the traffic stream; and

fp = factor to adjust for the effect of driver population.

In order to simplify the analysis the Freeway GPL was assumed to operate under the following ideal conditions:

1. twelve foot minimum lane widths,
2. six foot minimum lateral clearances,
3. all passenger cars and weekday commuters in the traffic stream, and
4. no interaction between adjacent freeway segments.

Under these conditions the adjustment factors, N, fw, fhv, and fp are equal to zero. the person capacity of each freeway GPL was then computed by multiplying the MSF (2,000 pcphpl at LOS E) by an average vehicle occupancy factor (AVO). These factors were obtained from the Washington State Department of Transportation Auto Occupancy Monitoring Program, Final Report prepared for the Puget Sound Council of Governments (PSCOG) by the Washington State Transportation Center (TRAC), 1990.

These calculations were performed at a number of screen line locations reflecting the highest regional use of I-90, I-405 and I-5. The averages resulting from these calculations are as follows:

2,000 pcphpl (LOS E) x 1.2(AVO) = 2,400 persons per hour

Calculation of the persons per hour capacity of a given freeway segment would follow the same process and N, in the equation above, would equal the number of freeway lanes in one direction.

During the peak hour at high demand locations, existing freeways are operating at level of Service (LOS) E or worse. The appropriate comparison is how many additional GPLs (or HOVs or Transitways or LRT lines) does it take to satisfy the existing and projected 2020 demand. This issue was analyzed in detail in the Screen line Capacity and Demand Study Technical Memorandum prepared by PB/KE dated August 1992.

Freeway HOV lane

The term capacity, as it is used to describe freeway general purpose lane operations, generally means maximum possible capacity. This condition is generally achieved only with the high-density traffic flow and speeds in the vicinity of 40 mph. Higher speeds can be sustained only when vehicular volumes are substantially below capacity. This condition is exacerbated when parallel GPL speeds are slowed during the peak period for non-barrier separated HOV lanes. Non-barrier separated HOV lanes operate safely with a differential speed no greater than 15 mph faster than parallel traffic. On a typical freeway, 55 mph speeds can be maintained only at volumes below 75 percent of capacity. Since HOV lanes must operate at or near the maximum legal speeds if they are to maintain their important travel time advantage, the above considerations limit the maximum volumes that can be carried without experiencing an unacceptable degradation of operational speed. The reference materials supporting these discussions are contained in the High Occupancy Vehicle Facilities Planning, Operating and Design Practices Manual, Parsons Brinckerhoff, October 1990.

Because HOV lanes have this unique combination of characteristics, there is no universally accepted procedure used to compute their capacity (or maximum service volume). In this study, HOV lane person-capacities at eight screen line locations were estimated using the transit procedures from Chapter 12 of the HCM as follows:

$$c_p = f'O_1 = [(MSFi - 2.5f')O_2]$$

where

c_p = total person capacity, in persons per hour,

f' = number of buses per hour,

O_1 = bus occupancy,

O_2 = car occupancy

MSF_i - maximum service flow rate for level of service i, in pcphpl.

In this equation the number of buses per hour is based on the number of routes scheduled past each screen line location during the peak hour for each alternative. The number of cars then reflects the auto capacity of the facility after subtracting the passenger car equivalents of the bases (assumed to be 2.5). The total person capacity then represents the number of people that can be carried by the specified number of buses and the remaining passenger car capacity.

In calculating the HOV lane capacities, the maximum service flow rate was limited to 2,400 vph in order to maintain operations at an approximate LOS C. Average bus and car occupancies were assumed to be 40 and, two to three respectively. The implications of these assumptions are addressed in the Washington State Freeway HOV System Policy Executive Summary, November, 1992. Using these assumptions resulted in the following capacity estimates:

(95 buses x 40 persons/bus) + (1,162 cars x 2 persons/car) = 6,124 persons/hour

(95 buses x 40 persons/bus) + (1,162 cars x 3 persons/car) = 7,286 persons/hour

These estimates were then modified to reflect the efficiency of the HOV in terms of the capital investments made in access and egress facilities resulting in a range of 4,800 to 5,700 persons per hour; approximately 80 percent of the calculated capacity.

Transitway Lane

High person capacities can be achieved by assuming that an exclusive bus operation would occur on the Transitway facility. With a maximum flow rate of 1,400 vph, a passenger car equivalency factor of 2.5, and an average bus occupancy of 40, a theoretical way capacity of 560 buses per lane per hour or 22,400 persons per lane per hour could be achieved under this scenario. However, use of this theoretical capacity would not accurately reflect the transit service or capital elements planned for each alternative. Accommodating this type of bus flow would require a much larger capital investment in entrance ramps, exit ramps, priority treatments, terminal facilities, and vehicles than is currently planned. For these reasons Transitway capacity was estimated as follows:

235 buses/hour x 40 persons/bus = 9,400 persons/hour

In this estimate the 235 buses per hour represents the maximum number of buses that could be accommodated given projected demand and the programmed capital investment.

Light Rail Line

The capacity of a rail transit line is determined by the lesser of the computed way capacity or station capacity. Typically, station capacity governs since the minimum achievable headway between successive trains is much longer at stations than between moving trains along line sections between stations. It is a function of train-station platform length, vehicle size, allowable passenger loading densities, and the minimum headway between trains.

Rail line passenger capacities in the peak direction during the peak hour were estimated from the following:

$$\text{Passengers/hour} = \frac{\text{Trains}}{\text{Hour}} \times \frac{\text{Cars}}{\text{Train}} \times \frac{Ft_2}{\text{Car}} : \frac{Ft_1}{\text{Passenger}}$$

The number of trains per hour or minimum headway that can be accommodated is dependent on several factors. These include train length, type of train control system (manual versus block signals), and station dwell time which is dependent on platform design (low versus high), method of fare collection (Prepayment versus pay on train), and number of doors per train. Previous studies, which assumed block signaling systems, high platform stations, prepaid fare collection, four doors per side of vehicle, and station dwell times less than 40 seconds, concluded that the practical minimum headway for the RTP Rail Alternative is about 90 seconds.

To compute the rail line capacities, a 90 second minimum headway was used as a combined headway for the rail routes that merge in the Downtown Seattle Transit Tunnel (DSTT). Using this 90 second headway and assuming four cars trains carrying 140 passengers per car, the maximum rail line capacity in excess of 22,000 passengers per hour in each direction (40 trains per hour per direction x 4 cars per train x 140 passengers per car = 22,400 passengers). The Federal Transit Administration (formerly UMTA) has issued a Procedures and Technical Methods Manual for Transit Project Planning, September 19186, which served as a reference to support this analysis.

The rail capacity number (22,000 passengers per hour in each direction) is higher than is expected to be achieved by the year 2020. It reflects a potential capacity which can be achieved in the future.