Comparison of Link light rail versus Bus Rapid Transit trunk line capacity

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This whitepaper compares the people moving capacity of light rail (LRT) and bus rapid transit (BRT) in the I-5 and I-90 corridors. It compares their ultimate trunk line capacities one against another, and it compares ultimate capacity with forecasts of how much capacity Sound Transit plans to provide, and use, in the year 2020. The objective of the paper is to determine whether trunk line capacity is a valid criterion for choosing one technology over the other, and if so which technology is superior .

All figures used herein refer to one-way capacity or volume on a single track or HOV lane. The key metric is persons/hr (or pph) past a given point, such as across the ship canal bridge. Data is drawn from the transportation literature, Sound Transit reports, transportation agency web sites, and personal contact with staff in non-Puget Sound transportation agencies. Key results are summarized in three charts inserted mid document.

The capacity issue is relevant for two reasons. First, the RTA (predecessor to Sound Transit) considered ultimate capacity a key justification for favoring one technology over another in the 1993 Final Environmental Impact Statement. At the time the RTA used it as reason for dismissing light rail, and bus alternatives (Ref 1: p. 2-49 to 2-51, 2-58, 2-59, 2-61,2-62). Although not listed as an official criterion, the Final EIS also used capacity as a way of discriminating against the Transitway alternative. (Ref 1: p.xxx)

Secondly, some people still think buses have insufficient trunk line capacity to meet the region's long-term needs along the north south "spine". At the same time they believe light rail does have adequate capacity. They see capacity as the overriding strategic reason for building light rail. Do the facts support these beliefs?

This paper has a narrow scope. Those interested in a broad overview of the rail vs. bus issue are referred to a most interesting paper by Hersher. (Ref 12))

Ultimate light rail capacity

The ultimate trunk line capacity of Link light rail is limited by three major constraints: station platform length in the Downtown Seattle Transit Tunnel (DSTT), the length of trains that can operate on surface streets in the Rainier valley, and the minimum headway between trains. The first two factors limit train length to about 360 feet, which translates to four car trains. Sound Transit's Final EIS assumed each train could carry as many as 533 passengers. (Ref 2: p3-7) The more recent Fleet Management Plan dated July 2000, assumes 74 seats per car and 63 standees for a total of 137 passengers per car. (Ref 4: p.13) This translates into 548 passengers per train. The more recent EA for the Initial Segment repeats these assumptions. (Ref 3: Appendix L, p. 23)

Sound Transit assumes trains could be operated on headways as short as two minutes. (Ref 3: Appendix L, p. 23). Using thirty trains per hour and 548 passengers per train, Sound Transit concludes Link's ultimate capacity is 16,440 persons per hour in each direction. This represents Link's maximum ever one-way capacity, and is based on almost half the passengers standing. It only applies only to the north line (through the DSTT and on to Northgate). Capacities elsewhere are lower because two-minute headways are not possible on the south line or on a potential east line along I-90.

The March 1993 FEIS asserts "Conventional transit practice and highway standards suggest that when train frequencies are under 6 minutes, cross traffic on arterials will be affected to the extent that grade separation is necessary….These constraints limit the capacity of surface LRT systems as compared to grade separated systems." (93 FEIS, p2-50) These statements imply that the very minimum headway in the Rainier valley --and thus on the entire south line-- can be no less than 6 minutes. Assuming six-minute headways, the ultimate capacity of the south line is 5480 pph.

Assuming that any future east line via I-90 is 100% grade separated so that sub 6-minute headways were possible, it would be theoretically possible to interleave eastside trains running on as little as 3 minute headways with south end trains on 6 minute headways thus obtaining 2 minute headways in the DSTT. In this case the east line would run 20 trains per hour and have an ultimate capacity of 10,960 pph.

It is the authors understanding that no single US light rail line operates at under 2.5 minute headways, and the scheduling reliability that would be needed to smoothly merge east side trains with south end trains may well mean that 2 minute headways in the DSTT are unrealistic. Thus the above capacities should be viewed as best case for light rail. They also assume a full standing load .

Ultimate bus rapid transit capacity

For bus rapid transit to reach its <u>ultimate</u> people moving capacity, it --like rail-- needs to operate on an exclusive "guideway". With buses this guideway is called a busway, or a pair of HOV lanes dedicated entirely to buses. Just as light rail's ultimate capacity assumes a pair of rails running up and down the I-5 and I-90 corridors, this analysis of BRT's ultimate capacity assumes a pair of HOV lanes doing the same thing.

Of course a continuous set of HOV lanes on I-5 and I-90 does not yet exist. However constructing them would not require widening either freeway. Most of the concrete is already in place, in the form of the reversible express lanes. In the 1993 FEIS one of the alternatives considered was a "Transitway/TSM" alternative. It was based on converting the I-5 and I-90 express lanes into bi-directional busways. Presumably this study established that such a conversion was technically possible. (Ref 1: p 2-18). Since 1993 there have been other studies of HOV lanes through downtown. Ref 9 has a diagram showing how the westernmost of the express lanes could be permanently dedicate to southbound traffic thus creating a two-way HOV facility from Northgate into downtown. (Ref 9: Fig.3-3 and p.3-27) See also Ref 10.

For purposes of citing the ultimate capacity of BRT it is assumed these HOV lanes are dedicated to BRT. However, at realistic levels of transit demand there would be space for other HOV vehicles to intermingle with the buses. The number of these other HOV vehicles could be managed to whatever level keeps the lanes flowing at 50+ MPH, such as is done with parts of the Houston HOV system. Letting other vehicles share these lanes is a boon to car and vanpool usage, and it obtains the best lane throughput until that distant day when there are enough buses to fill the lanes. Having discussed right of way, I next address the matter of ultimate capacity.

There are several ways to estimate the ultimate capacity of a stream of buses on a bus-only lane. We start with bus capacity. Sound Transit's November 1999 FEIS states that a 40 foot bus can carry 40 seated passengers or with standees a total of 52. The same table states that 60-foot buses can seat 60 passengers or with standees carry 78 persons total. Next we need to know the maximum number of buses per hour.

As you drive the freeway you will find that staying about 3 seconds behind the preceding vehicle feels quite safe at 50 or 60 MPH. Three-second headways translates to 1200 vehicles per hour. On page 2-2 the Transit Capacity and Quality of Service Manual assumes a freeway lane can carry about 2300 autos per hour and that a bus would be equivalent to two automobiles. If so a freeway lane could carry 1150 buses per hour.

Assuming 1150 buses per hour at 78 persons per bus means one HOV lane used exclusively for Bus Rapid Transit has an ultimate capacity of 89,700 persons per hour with standees, or 69,000 with all seated.

Elsewhere the Transit Capacity and Quality of Service Manual mentions a "minimum operating threshold of 800 to 1000 buses per hour on a HOV lane. 800 buses per hour translate to 62,400 seated plus standing persons per hour.

In the real world there is probably no place where passenger demand is high enough to require all that capacity. There may be larger numbers in Asia but the highest actual busway volume the author has seen cited in the literature is 735 buses per hour in the peak direction in New York's Lincoln Tunnel. (Ref 7, p 2-40) This source does not cite ridership but it does show that it is physically possible to move at least 735 buses per hour past a point. If max capacity were needed these could presumably be 78 passenger buses in which case capacity would be 57,330 persons per hour. Or assuming 60 seated passengers per bus, 44,100 pph.

It does not matter which of the above is more accurate since all indicate BRT capacities far in excess of what Link light rail can carry, and indeed what the region will require. To be conservative the BRT bars in the charts below were scaled to 40,000 pph, even though --as indicated on the label-- the ultimate seated capacity of BRT is almost certainly well over 50,000.

As to actual BRT passenger volumes "Many BRT lines in South American cities carry peak-hour passenger flows that equal or exceed those on many U.S. and Canadian fully grade-separated rail rapid transit lines." (Ref 8, p.5)

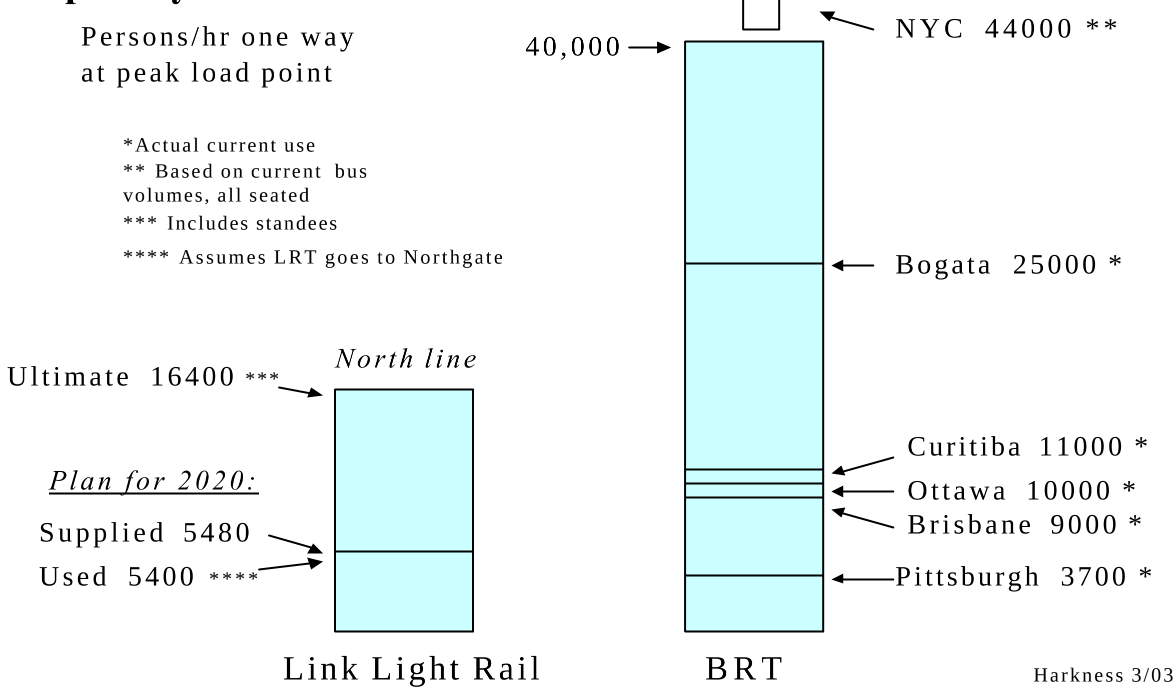
The highest number cited is 25,000 pph in the peak direction on Bogotá's TransMillenio system. (Ref 8, p.5) The authors reference another study, which states there are other South American BRT lines carrying from 10,000 to 20,000 pph. (Ref 8, p.20) The famous BRT system in Curitiba Brazil carries 339,000 riders per day, with the highest peak-hour peak-direction volume on one line being 11,000 pph. (Ref 8, p.21)

Brisbane's BRT system runs 200 buses per hour carrying 9000 pph at the peak load point, while Ottawa's BRT carries 10,000 pph at the peak load point. (Ref 6, p. 167) Pittsburgh is currently running 96 buses per hour at the peak load point on the east busway. The associated passenger volume is 3700 pph. (personal communication with Port Authority staff, Feb. 2003) These actual passenger volumes are plotted on the bar chart below.

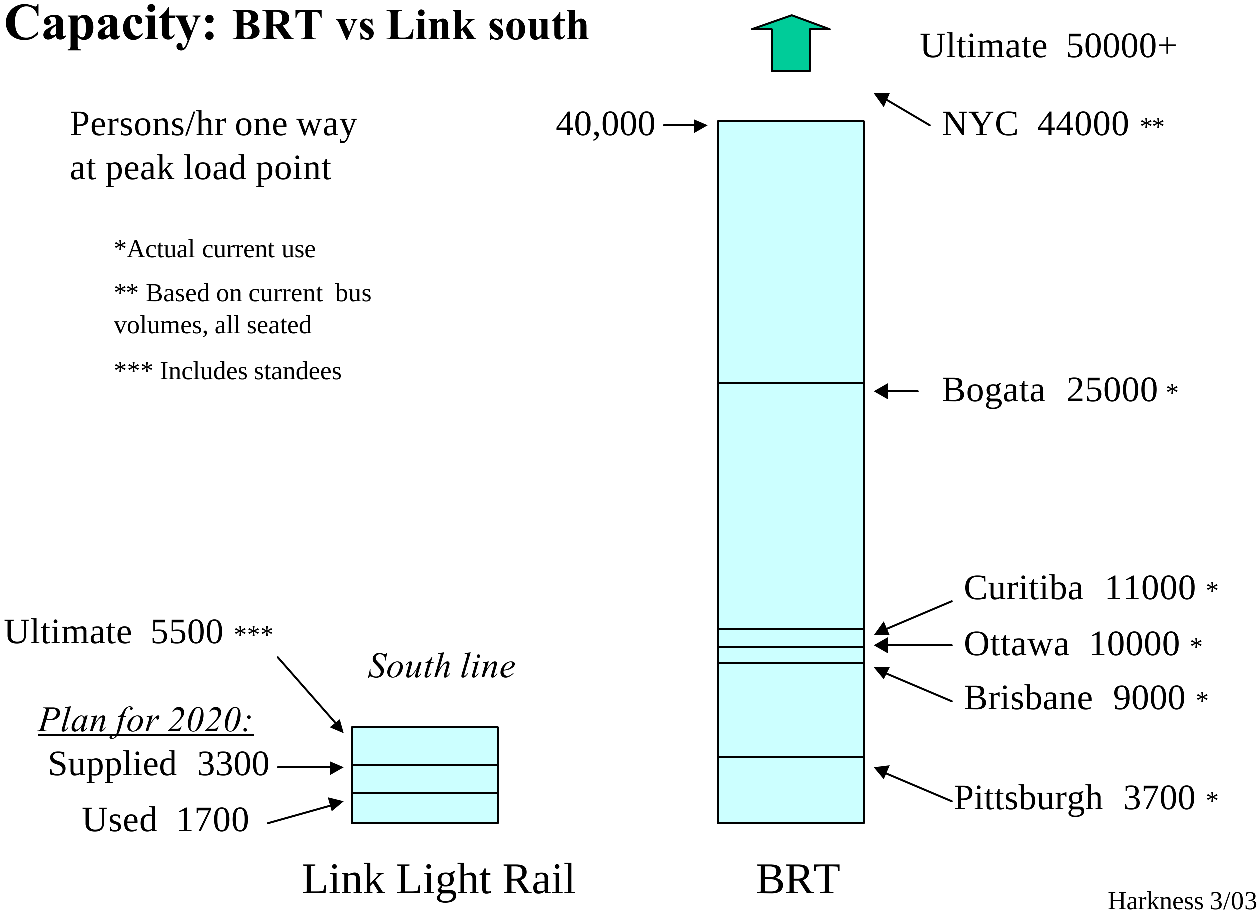
In sum, available data shows that BRT operating on an exclusive lane has a demonstrated one way capacity of 25,000 pph and a theoretical capacity well above 50,000 pph.

It is interesting to note what Sound Transit’s predecessor agency said about ultimate BRT capacity in their 1993 FEIS, which compared heavy rail against a busway alternative. "The theoretical per direction capacity of a busway, or barrier separated lane for exclusive use for buses, is approximately 22,000 persons per hour in one direction past a single point." (Ref 1: p.xviii). Amazingly enough operators of the New York busway and Bogotá's TransMillenio are already far exceeding what Sound Transit asserts is the theoretical limit for BRT.

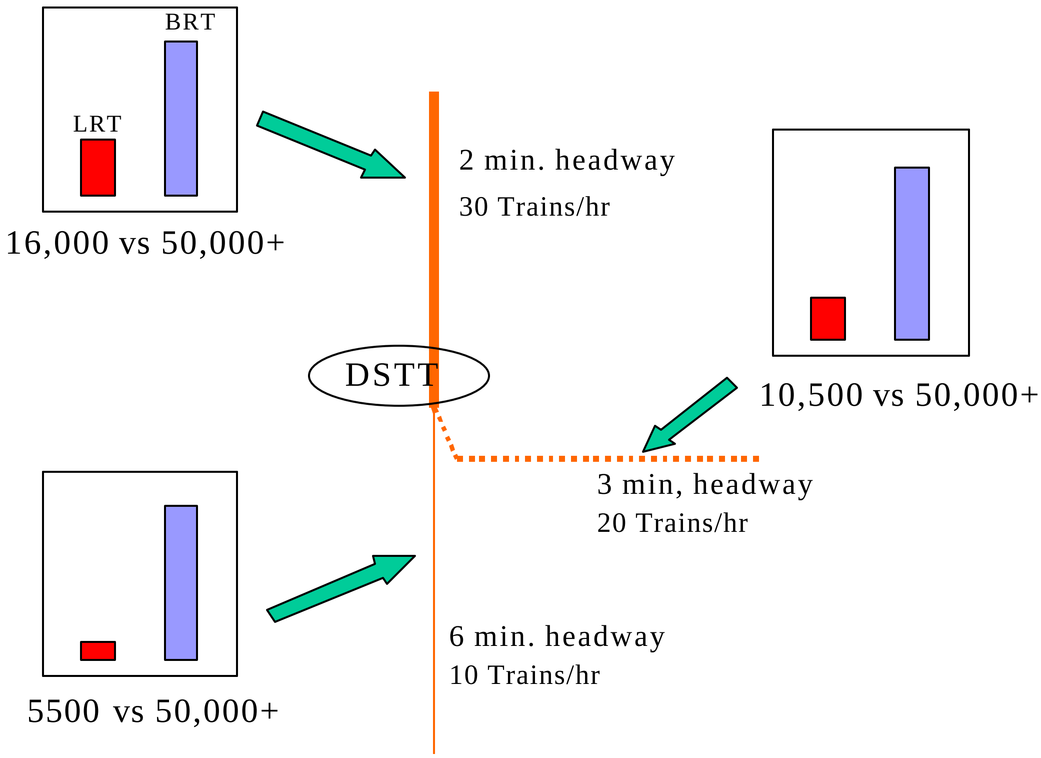
Capacity: BRT vs Link north



Capacity: BRT vs Link south



Ultimate capacity: Link LRT vs. BRT



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Forecast capacity needs

How much capacity does the Puget Sound transit backbone actually need? How much does Sound Transit actually plan to provide using light rail? Do either of these even come close to the limits of what light rail or BRT could actually provide? Is one technology able to meet the forecast demand while the other isn't?

The number of people that will actually ride transit on the core routes into Seattle is dependent on the quality of the transit system. A system that extends farther out from downtown, involves fewer transfers, runs more frequently, and travels faster will garner more passengers than one that doesn't. That's the generalization. What are the specifics?

The highest forecast of estimated transit demand the author has located is for a peak demand of 15,000 pph in 2020. (Ref 1: p.2-58) That was apparently predicted in the 1993 FEIS for a 125-mile fully grade separated heavy rail system. There were no details explaining how this figure was derived. This same 15,000 pph "long range ridership projection" is repeated in the more recent EIS's for light rail, again with no indication of how it was derived. (Ref 3: Appendix L, p.23)

Sound Transit's "Operating Plan" for the original 21 mile light rail proposed a 2020 peak period headway of 5 minutes on the north line and 10 minutes on the south line using trains having a full standing load capacity of 533 persons. (Ref 2: Table 3.2-1 and Appendix M.2, page M.2-1). With a 5-minute headway the north line would have a capacity of 6400 pph, while the capacity of the south line would be 3200 pph. This is the full standing load capacity that Sound Transit actually planed to provide at the time the FEIS was published in Nov 1999.

The more recent July 2000 Fleet Management Plan assumed the line would extend to Northgate and on that basis said there would be 6-minute headways on the north line and 10 minutes on the south line. (Ref 4: p. 20) It also assumed 548 rather than 533 persons per train. The respective full standing load capacities (<u>supply</u>) would be 5480 pph on the north line and 3288 pph on the south line.

That same report has a chart comparing supply with demand. (Ref 4: p.24) It shows that year 2020 peak load point <u>demand</u> is expected to total about 5400 pph on the north line and 1700 pph on the south line. If the line did not extend to Northgate these volumes would be lower.

To put this into perspective, 91 buses per hour (with everyone seated) could handle as many passengers as Link light rail is expected to carry on the north line in the year 2020. Twenty eight buses per hour could handle projected demand on Links south line. These are small numbers and could easily be carried by a BRT system. These bus volumes are nothing compared to the 735 buses per hour in New York's Lincoln Tunnel. Indeed they are about 70 buses per hour operating in the DSTT today, and that's only about half the tunnels capacity.

Ability to fully utilize trunk line capacity.

A comparison of ultimate trunk line capacity is only part of the overall capacity issue. As noted above there may not be anywhere near enough demand to make ultimate capacity a relevant consideration. A second issue is the ability or inability to actually utilize the ultimate trunk capacity even if the demand did exist.

For rail systems to utilize their ultimate capacity, there must be sufficient feeder bus access to the rail stations, enough nearby park and ride spaces, and/or enough people within walking distance of stations. Shortcomings in any of these areas could limit the useable capacity of light rail. For instance, for rail to use its full 16,400 pph capacity on the north line it must be possible for a large number of buses to access the U District or Northgate station, and there must be large park and ride lots adjacent the stations. Since all light rail trains must transit the DSTT the ultimate useable capacity of Link light rail through downtown is 16,400 pph in each direction, assuming that there are no limits in getting people to and from the stations.

On the other hand, for BRT trunk lines to reach full utilization it is necessary to have enough on-off ramps and loading areas on the suburban end(s) or the BRT routes. On the downtown end there must be adequate egress ramps and adequate loading areas. BRT has an advantage in that load off load areas don't need to be right along the freeway. For example buses could load/off load in the center of the University District, then traverse over to the I-5 busway. On the downtown end they can split off and load in various areas, as Metro, Community Transit and Sound Transit routes do presently.

To better image this, imagine some distant future time when the bus handling capacity of the DSTT has been reached and there are say 25,000 pph coming south across the ship canal on a fleet of BRT buses in the HOV lanes. In this event the buses would be organized into three groups. One for persons destined for areas near the DSTT, one for those destined to south lake union and other downtown locations not adjacent the DSTT, and a third group for those going to all destinations south of downtown. The first group would go through the DSTT to unload. The second group would exit the HOV lanes at Mercer or other downtown exits (many or most of which already exist). The final group would stay on the HOV lanes and continue south through downtown.

If these HOV lanes and access ramps exist (as previous plans have already envisioned) the usable capacity of BRT up and down the I-5 spine is truly enormous. It's certainly far greater than light rail, which is limited to 16,400 under the best of circumstances.

Bus versus rail on I-90

Although there are technical uncertainties about being able to put light rail on the existing I-90 bridge, I will assume here that the I-90 express lanes can be converted into either a two way HOV facility, or used for light rail. Used for BRT their ultimate capacity is 50,000 pph. Used for light rail their ultimate capacity is 11,000 pph. Clearly BRT is the better choice for those wishing to provide maximum transit capacity into the distant future.

In the more likely situation that mass transit demand is under 11,000 pph for many years, it would still be a mistake to preempt the express lanes for light rail because it would reduce the throughput of those lanes. For instance lets assume mass transit demand were 5000 pph. That could be handled by 83 BRT buses per hour, and --assuming lane capacity is 1000 vehicles per hour -- still leave room for 917 other HOV vehicles. They would include carpools, vanpools, school buses, emergency vehicles, utility crew trucks, and other multi-passenger vehicles. The combined capacity of the lane becomes the 5000 pph carried on BRT plus whatever these other HOV vehicles handle. By definition, the total exceeds the 5000 that a rail only scenario could accommodate. In sum, HOV operations in the I-90 express lanes would provide more people moving benefit than would conversion to light rail. This is true regardless of the level of mass transit demand. It is true in the near term, the intermediate term, and the long term.

The above analysis shows why light rail will probably never be built in the I-90 corridor.

If light rail does not go over I-90, capacity in the DSTT will be wasted and the region will not obtain maximum benefit from the DSTT. However, getting the best utilization of the DSTT is a separate issue that the author has treated elsewhere.

Conclusions

- The trunk line capacity of Sound Transit's proposed Link light rail is severely constrained by local conditions particular to Seattle, namely station length in the DSTT and on-street operations in the Rainier Valley. Link light rail has nowhere near the people moving ability of heavy rail systems like BART or the Washington DC METRO.

- Capacity on Links south line is limited to one third of what the north line could carry. This forever shortchanges the entire south end in terms of regional transit capacity.

- The likelihood of building light rail in the I-90 corridor is remote since it would reduce the people moving capacity in that corridor to well below what a mix of BRT and other HOV vehicles could achieve.

- Buses operating on HOV lanes are capable of carrying several times more passengers than Link light rail will ever be able to carry. If ultimate trunk line capacity is the issue, BRT wins. If the intent is to invest in transit with enough capacity to handle Puget Sound's needs far into the indefinite future, BRT is the better choice.

- Sound Transit's estimated year 2020 passenger demand for Link light rail is far below the systems capacity, and could easily be handled by a modest BRT system.

- Understanding the ultimate useable capacity of either light rail or BRT requires additional analysis of how people will access the rail stations or how buses will access the HOV lanes under full load assumptions. (The light rail FEIS looked at access under forecast demand, not full demand, conditions.) There may be constraints that would limit how many people could actually access the line haul facility.

- Demand, not supply, should be everyone's main concern. Given that forecast transit demand is much lower than either light rail or buses could handle --the DSTT is only operating at half capacity today and Sound Transit only expects light rail to operate at about one third capacity twenty years from now--, ultimate trunk line capacity, or even ultimate usable trunk line capacity, is probably not a valid criterion for favoring light rail over buses, or vice versa. This is especially true on the north line where both technologies have far more capacity (supply) than the region is forecast to demand over the next 20 years. A possible exception is Links south line. It has quite a low capacity and may not be sufficient to meet long term needs.

- A misplaced focus on capacity has been diverting attention from the real issue. The real issue is: for an investment of X Billion dollars, which technology can attract the most riders? The GAO study and other research strongly suggest the answer is bus rapid transit, since more route miles can be built for the same cost.

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