[This is my section of a 3-person project on bus rapid transit. This section, Section 1, is an introduction. Section 2 was a review of case studies and Section 3 was a proposed implementation.]

Bus Rapid Transit: Introduction

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Bus rapid transit (BRT) is, exactly as the name states, rapid transit provided by busses. It is hard to define BRT more precisely since actual implementations vary a great deal, but a good implementation generally involves a number of the following features[1]:

(1) bus stations with amenities,
(2) well designed vehicles,
(3) a mechanism for rapid fare payment,
(4) use of Intelligent Transportation Systems (ITSs),
(5) dedicated roadway space, and
(6) frequent all day service.

These features – generally the more the better – should be integrated into a system with a unique identity. Some successful BRT implementations have all of these features (e.g., Curitiba and Bogotá), and some very few (e.g., Lincoln Tunnel exclusive bus lanes). Ultimately BRT should provide a high level of transit service using vehicles with rubber tires. The above features allow for busses to offer this level of service. These features can (and should) make BRT a favorable enough mode to attract choice riders (in addition to current transit users). To achieve this, BRT needs to meet the travel requirements of the population (that is, take riders from easy-to-get-to bus stations to useful destinations) in a fast, reliable, comfortable manner. Below I will consider the costs and benefits of BRT, and then each of the above features.

BRT: *Costs and benefits*

Benefits. BRT is sometimes referred to as "rubber-tired light rail transit (LRT)", trying to "cash in" on the generally positive image of LRT. While such a statement is true to an extent, it misses the reasons BRT can be the best transit choice for some areas. BRT offers many benefits, but two are particularly important since no other mode can offer them to the extent that BRT can: (1) incremental system development, and (2) operational flexibility.

Incremental system development can spread the capital costs over time while allowing for phased improvements and testing. If development is incremental, it is important to choose an initial segment – or set of features – that adequately demonstrates the benefits of BRT. This will help build support for BRT, facilitating system expansion and improvements. (In some cases it will make the most sense to build from the "outside-in" rather than starting with a more costly, shorter downtown segment.[2] In other cases, a downtown segment might make the most sense. In yet other cases a full network without all the features will make the most sense. And so on.) In all cases, soliciting feedback and collecting data on the system – that is testing the system – should be done professionally and the resulting lessons should be applied going forward.

BRT offers operational flexibility along a number of different dimensions. Flexible routing is due to the fact that BRT busses can generally run on regular streets. For example, feeder service (on regular streets) and line-haul service (on exclusive or semi-exclusive running ways) can be combined, reducing the need for transfers. The carrying capacity of busses is also quite flexible since the same running way can generally be used for small and large busses. In addition, busses can generally divert around obstacles on the running way.

Other benefits of BRT – that are not unique to BRT as a transit mode but are still important – include[3]: (1) Increased transit ridership: e.g., 30% in Los Angeles, 50% in Boston, and 80% in Miami. (2) Travel time savings: about 30% for exclusive and semi-exclusive running ways. (3) Reduced pollution due to less fuel use per person. (4) Increased land development and value around stations.[4]

Finally, the capacity of most BRT systems is less than that of most LRT systems. In some cases this would be considered a negative, but, since the capacity is actually plenty for most North American cities[5], this is a positive.

Costs. BRT is, on average, cheaper than LRT to implement and operate, but the costs for both modes have high variance. My one-sentence summary is the following: The cost of a high-end BRT implementation is around the cost of a low-end LRT implementation.[6]

BRT: *Features*

Bus stations/stops/terminals. Facilities used to access BRT can be broken down into three categories: stations, stops, and terminals (though terminology varies by implementation).

BRT stations should be permanent, comfortable (including weather protection, adequate lighting, telephones, and other amenities), safe (both in terms of riders' perception and in actuality), provide clear and coordinated information (real-time information being best), enforce the overall system identity, and provide adequate circulation space. Stations need to be accessible by the disabled, pedestrians, hopefully bicyclists, and possibly automobiles[7].

BRT stops are similar to regular bus stops, and thus should only be used in low-density feeder areas that do not have high demand. BRT terminals should have a level of features at least as high as stations. If intermodal, service and information needs to be integrated across modes.

Vehicles. [8] BRT vehicles should be well designed and match demand. Features that make a BRT vehicle "well designed" include: easy and quick to enter and exist, comfortable to ride in, visually pleasing internally and externally (adding to the system identity), and environmentally friendly (in terms of air and noise emissions and vibrations). (Regular bus features, such as air conditioning, good lighting and windows, etc. should not be neglected.)

It is very important that the busses be easy and quick to enter and exit, in order to reduce dwell times (and thus increase the overall journey speed). This can be facilitated by low-floor busses, an adequate number of doors, and wide internal aisles.[9] (Adequate circulation space at stations – mentioned before – along with rapid fare payment, guidance technology, and exclusive running ways – discussed later – also help.) Why is this so important? Because *travel time savings is the most important factor in attracting riders* (reliability is probably the second most important).[10] A 1% decline in travel time can produce a 1% increase in ridership![11]

Fare payment. Rapid fare payment is very important in reducing dwell time. "Off-board" payment methods allow for the most rapid boarding. These methods include: controlled access, proof-of-payment, and free-fare zones. "On-board" methods, from generally fastest to slowest[12], are (1) smart cards, (2) single tokens or tickets, (3) exact change, and (4) swipe or dip cards. As bus usage increases (as should be aimed for), rapid payment becomes even more important since there are more people entering each bus (particularly at high-demand stations).

Intelligent Transportation Systems (ITSs). Thoughtful use of ITSs can greatly enhance the performance of a BRT system. Four uses are discussed below.

Automatic Vehicle Location (AVL) requires a way of determining where busses are, a way of getting that information to a central processing center, and the ability to process and disseminate the information. AVL can be used to provide real-time information to riders (on electronic message boards at stations, via the internet, via cell phones, etc.), control bus headways, keep busses on schedule (improving timed transfers), and respond quicker to vehicle breakdowns.[13] AVL is so useful that it has been reported to actually reduce costs while increasing ridership.[14]

Signal prioritization – that is, prioritizing busses over low-occupancy-vehicles at signaled intersections – can increase journey speed[15] and reliability. There are three basic methods of accomplishing this: (i) a red signal can turn green sooner, (ii) a green signal can stay green longer, or (iii) a special transit phase can be activated.[16] (Signal prioritization can be problematic in dense urban areas with short blocks.)

Automatic passenger counters are an efficient way to collect ridership information. Also, counter data can be used (in conjunction with AVL) to dispatch additional busses, in real-time, when additional capacity is needed.

Guidance technology can guide busses along a running way. (There are optical, magnetic, and mechanical methods of guidance.) This technology is incorporated into both the vehicle and the running way. Guidance can reduce the necessary lane width, allow for precision docking at stations (speeding entrances and exits), make for a smoother ride, and increase safe bus speeds. However, there are some technical and operational issues.[17]

Running ways. BRT running ways (that is, the surfaces that busses run on) range from exclusive busways to regular street lanes. Generally, the more exclusive the running way, the more reliable and speedy the service. (AVL, rapid fare payment, rapid boarding/exiting, etc. also help.) Regular street lanes ("mixed traffic operation") typically achieve the poorest BRT performance, but can be useful along low-density collector-portions of routes. Exclusive (or semi-exclusive) running ways are appropriate for line-haul portions of routes and, where feasible, downtown distribution. Achievable capacity increases with exclusivity.[18] An exclusive running way must, of course, exclude vehicles that should not be on the running way.[19]

(There are many other design issues that I will not discuss here, but some of them are: Should there be bus bulbs for on-street stops? How will trucks access the curb if the running way is next to the curb? How will turns from regular vehicles interact with the running way? Does the roadway geometry need to be changed to accommodate bus turns? And so on.)

Service. BRT service should be frequent and all day. (This also helps with lane enforcement and system identity.) There are guidelines for BRT service[20], but, basically, the frequency of service and hours of operation should be appropriate for the market being served.

A few other issues to consider, that broadly fall under this category, are as follows.

(1) The spacing between bus stations needs to strike a balance between speedy service (far apart stations) and convenient service (close together stations).[21]

(2) There is a trade-off between the number of routes and the frequency of service. (More routes provide more options, but less frequent service.) A compromise needs to be achieved and it is generally better to tend towards fewer routes and higher service frequency.[22]

(3) It is often useful to have multiple types of service: local (all-stop), express (limited-stop), and commuter (and possibly dedicated feeder and/or connector service).[23] Multiple types of service will require a larger running way envelope at bus stations to allow for passing busses.

(4) Finally, service information (such as bus arrival times) should be provided in real-time.

BRT: *Additional issues*

Busses are quite susceptible to "modal bias". That is, there is a general belief that rail transit is inherently superior to bus transit. This presents an image problem. To counteract this, a BRT system needs to offer a high quality of service (speedy, reliable, comfortable, clean, convenient, integrated, and so on). This level of service needs to be emphasized in marketing/advertising and educational outreach to potential riders. Since the BRT vehicles and stations are the main "visual representatives" of the system, they need to be particularly well designed and visually pleasing, enforcing the system identity/image. (A system should also have a user friendly – and image enhancing – website that provides clear and coordinated information.)

Finally, BRT usually involves complex institutional arrangements since many different groups are involved, from transportation departments and transit agencies, to public officials and public citizens. All of these groups should be involved from an early stage of the project so that (1) their knowledge and input can be used and (2) they are more likely to "buy in" to BRT.

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[1] See Transit Cooperative Research Program (TCRP), Report 90, *Bus Rapid Transit Volume 1*, 2003. See also Federal Transit Adminstration (FTA) & United States Department of Transportation (USDOT), *Characteristics of Bus Rapid Transit*, 2004.

[2] As was done in Ottawa. (Page 9-12, TCRP, Report 90, *Bus Rapid Transit Volume 2*, 2003. Also, chapter 9, Cervero, *The Transit Metropolis*, 1998.)

[3] Pages 9-2 to 9-3, TCRP, Report 90, *Bus Rapid Transit Volume 2*, 2003.

[4] The extent of these increases depends to a great extent on supportive land use policies that encourage development (and the general real estate market).

[5] Pages 2-4 to 2-5, TCRP, Report 90, *Bus Rapid Transit Volume 2*, 2003.

[6] <u>Capital cost comparison: Running ways</u>

BRT running ways cost, in millions per mile, about $300 for bus tunnels, $7 for at-grade and arterial median busways, $5 for guided bus operations, and $1 for mixed traffic and/or curb lanes. (Page 9-3, TCRP, Report 90, *Bus Rapid Transit Volume 2*, 2003.) Compare that to LRT costs of about $10 to $100 million per mile. (Page 497, Grava, *Urban Transportation Systems*, 2003.)

<u>Capital cost comparison: Vehicles</u>

BRT "purpose built" vehicles cost about $1 million; standard articulated busses cost about $500,000. (Page S-11, TCRP, Report 90, *Bus Rapid Transit Volume 2*, 2003.) Compare that to LRT costs of about $1-$2 million per vehicle. (Page 498, Grava, *Urban Transportation Systems*, 2003.)

<u>Operating cost comparison</u>

The operating costs of BRT and LRT have been compared in Dallas, Denver, Los Angeles, Pittsburgh, San Diego, and San Jose. BRT operating costs exceed those of LRT in San Diego in per-vehicle-revenue-hour ($100 vs $89), in San Diego and San Jose in per-unlinked-passenger-trip ($5.60 vs $1.19 and $5.10 vs $4.07), and in none of these locations in per-vehicle-revenue-mile. (Values taken from figures 7-9, U.S. General Accounting Office, *Mass Transit: Bus Rapid Transit Shows Promise*, 2001.)

[7] In suburban areas, automobiles need to be considered. A park-and-ride facility may be necessary. But this needs to be considered in the context of land use planning. That is, if dense development around BRT stations is desired, less parking should be included. But if the BRT station is in a low-density area – and there is no desire to increase the density – a lack of parking will greatly diminish the utility of the service. In dense urban areas, no special accommodations should be made for automobiles.

[8] Many beautiful and interesting BRT "purpose built" vehicles (with detailed specs) can be found in the U.S. Department of Transportation & FTA, *Vehicle catalog: A compendium of vehicles for BRT service*, 2003. Note that regular busses can be used for BRT service, though the level of service will be lower. (This might be the first stage

in an incremental system development.) To save money while providing better service, regular busses can be up-fitted with ITSs technology. (WestStart-CALSTART, *Bus Rapid Transit newsLane*, Vol 4, No 1.)

[9] Low-floor busses can reduce boarding times by 20%. Increasing from one boarding channel to two reduces boarding time by 40%. Specialized BRT vehicles are available with extra-wide aisles. (Pages 6-9, 6-6, and 6-2, TCRP, Report 90, *Bus Rapid Transit Volume 2*, 2003.)

[10] Pages 3-1 and 4-3, FTA & USDOT, *Characteristics of Bus Rapid Transit*, 2004.

[11] Los Angeles case study. (Page 31, TCRP, Report 90, *Bus Rapid Transit Volume 1*, 2003.)

[12] Page 8-11, TCRP, Report 90, *Bus Rapid Transit Volume 2*, 2003.

[13] Pages 7-1 to 7-7, TCRP, Report 90, *Bus Rapid Transit Volume 2*, 2003.

[14] Pages 7-16 to 7-18, TCRP, Report 90, *Bus Rapid Transit Volume 2*, 2003.

[15] Travel time savings of 5-10% are not uncommon. In at least one case, this enabled the size of the bus fleet to be reduced 10%. (Page 7-11, TCRP, Report 90, *Bus Rapid Transit Volume 2*, 2003.)

[16] Page 7-10, TCRP, Report 90, *Bus Rapid Transit Volume 2*, 2003.

[17] For example, if the system is mechanical it can be difficult for a bus to exist the running way at an unplanned point. If the system is optical, nature (or malicious persons) can reduce the visibility of the running way markings (though optical systems actually perform better than one might expect due to snow, leafs, and so on). Magnetic systems are the newest and least tested guidance technology.

[18] A curb bus lane on a city street can move at most 90-120 busses per hour, whereas busways can move over 200 busses per hour (a non-stop, well designed, exclusive freeway lane can accommodate 750-800 busses per hour). Note that, just because there is capacity, that does not mean there will be sufficient demand. An exclusive running way needs to have adequate usage (without a deterioration in service from too much usage). If the running way is not being used enough, a common option is the U.S. is to allow high-occupancy-vehicles to use the lane. (Pages 3-5 and 3-30, Report 90, *Bus Rapid Transit Volume 2*, 2003.)

[19] Grade-separated running ways are not so difficult to enforce (though require adequate signage at entrances and exits in particular), but at-grade running ways can be difficult to enforce. A physical barrier between the running way and the regular traffic lanes helps. Painting the running way with a special color can also help (and enforces the system identity). Other methods of enforcement include contra-flow (which is "self-enforcing" though has other practical issues such as running against traffic-light progression) and the straightforward method of fines (and towing). Fines can be facilitated by the use of camera and video technology.

[20] Guidelines suggest that a BRT line should, at a minimum, run 16 hours a day, have 8-10 minute headways during peak hours, and have 12-15 minute headways during off-peak hours. (Pages 2-4 to 2-5, TCRP, Report 90, *Bus Rapid Transit Volume 2*, 2003.)

[21] Guidelines based on the main arrival mode suggest station spacings of 0.25-0.33 miles for pedestrians, 0.5-1.0 miles for busses, and 2.0 miles for automobiles. (Page 5-3, TCRP, Report 90, *Bus Rapid Transit Volume 2*, 2003.)

[22] Page 8-1, TCRP, Report 90, *Bus Rapid Transit Volume 2*, 2003.

[23] Page 8-2, TCRP, Report 90, *Bus Rapid Transit Volume 2*, 2003.