
# Bus Rapid Transit and Carbon Offsets

Issues Paper

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# 1 Introduction and Key Conclusions

Bus Rapid Transit has generated considerable excitement among transportation planners and environmentalists in recent years. Spurred by showcase projects in Bogotá and Curitiba as well as examples in the U.S. such as Boston's Silver Line, planners have seen an opportunity to provide a similar quality and speed of service to light rail at a fraction of the cost. Even relatively modest BRT projects have shown large gains in transit ridership, with many of the riders switching from the private auto.

This paper provides an analysis of the potential to develop a carbon offset protocol for Bus Rapid Transit (BRT) projects, focused on the U.S. voluntary carbon market. It describes experience with the costs, ridership and emission impacts of BRT projects to date, and existing methodologies to quantify the emissions impacts of BRT, particularly those developed for the Clean Development Mechanism (CDM). It then analyzes key issues for a potential protocol, including development of the baseline scenario, quantifying leakages, and ownership of emission reduction credits. The paper concludes by providing an order-of-magnitude estimate of the emission reduction potential.

The paper is based on an extensive literature review, coupled with informal conversations and more in-depth interviews with staff at transit agencies, federal agencies, carbon offset developers and other organizations. It also draws on more than 30 formal interviews conducted as part of a separate research project at Stanford University, analyzing barriers to the approval of transportation methodologies in the CDM.

The key conclusions of this paper are as follows:

- BRT is difficult to define, as the concept embraces a large range of investments to improve operating speeds and service quality. However, it would be technically possible to develop a carbon offset protocol applicable to any corridor-based transit improvement, including modest transit signal priority measures and potentially light rail. Key issues such as baseline selection, additionality determination and monitoring would be very similar.
- The number of BRT projects in the U.S. is expected to grow rapidly, with at least 60 U.S. communities having BRT on at least one corridor by 2017.
- The ridership gains from BRT in the U.S. have been impressive in relative terms. There has been very little research quantifying greenhouse gas emission savings. However, these are likely to be modest in absolute terms. In Los Angeles (the site of the most extensive U.S. evaluation), annual $CO_2$ reductions from Metro Rapid service are about 0.3 metric tons per new daily rider. Given that a successful BRT corridor might attract a few thousand new daily riders, annual emission reductions might be measured in the hundreds rather than thousands of tons for most projects.
- Projects in developing countries are likely to have far greater potential, as BRT usually replaces a highly inefficient system with aging, small microbuses. Most emission reductions in developing countries are gained from the shift to cleaner and larger vehicles rather than modal shift.
- The methodology adopted for BRT in the CDM (AM00031) is extremely complex and poses numerous monitoring challenges. However, most of these derive from an exhaustive approach to quantifying leakages. There may be opportunities to simplify this methodology

for use in the U.S. voluntary market, in which case almost all data required would be collected by transit agencies on a routine basis. A rider survey would be the main new monitoring requirement.

- Carbon finance is likely to account for a very small share of capital costs for a BRT project. Emission reductions for Metro Rapid in Los Angeles are estimated at $117 per metric ton of $CO_2$ reduced, but the high passenger volumes and relatively modest costs of this project means that it is likely to fall at the lower end of the range. Other systems may have a cost of tens of thousands of dollars per ton of $CO_2$ reduced. Economic and other co-benefits (e.g., travel time savings) tend to far outweigh greenhouse gas emission benefits.
- The high cost of emission reductions (when excluding co-benefits) means that additionality testing is likely to rely on barrier analysis, as it has under the CDM. Lack of funding is one barrier to BRT, but local opposition to dedicated bus lanes or loss of parking may also be an important factor in some cities.
- Ultimately, the major barriers to an offset protocol for BRT are likely to be the relatively small emission reductions rather than methodological issues.

# 2 Bus Rapid Transit

## 2.1 Definition

There are a wide range of BRT systems in planning and operation, making a precise definition elusive. A recent Transportation Research Board study defines BRT as: "a flexible, rubber-tired form of rapid transit that combines stations, vehicles, services, running ways, and ITS [intelligent transportation system] elements into a fully integrated system with a strong image and identity."[1] More generally, BRT includes at least some of the following elements, with the overall objective of reducing travel times and often creating a premium-brand service:[2]

- **Running ways:** BRT often uses exclusive rights of way such as dedicated lanes or grade-separated facilities. In other cases, buses may receive priority at traffic signals, and other priority measures such as "queue jumps" at traffic signals or bus bulbs may be used to avoid delays in reentering the travel lane.
- **Stations:** BRT typically features stop improvements, ranging from enhanced shelters to station-like facilities. Stop spacing is usually much wider, or else a local service runs in parallel with a limited-stop rapid service, which also reduces travel times.
- **Vehicles:** New, articulated vehicles are often given a specific BRT branding to distinguish them from the regular bus fleet.
- **Services:** BRT services usually include increased frequencies and service spans (hours of operation).
- **Route structure:** A simplified route structure might include marked 'stations', similar to a rail map.
- **Fare collection:** Some BRT systems use fare prepayment to allow all-door boarding and reduce "dwell time" at stops.
- **Intelligent Transport Systems (ITS):** Technology enhancements might include real-time passenger information, computerized dispatch and/or signal priority.

BRT services can be best thought of as a continuum of project types, from enhanced bus services with branding, modest priority measures and limited stops to "full BRT" with dedicated rights-of-way, fare prepayment and station-like stops. The former is typified by AC Transit's Rapid service on San Pablo Avenue in Oakland, Berkeley and cities to the north. A good example of "full BRT" is the Orange Line in Los Angeles. Travel times for U.S. BRT systems are typically 20-47% less than the previous bus system on the same corridor.[3]

From the perspective of a carbon offset protocol, it may make sense to be as inclusive as possible. Indeed, any corridor-based transit improvements – be it rapid bus, Bus Rapid Transit (in whatever form) or light rail – might come under the scope of a single protocol. While the modes may differ in the magnitude of mode shift that is realized and the type of vehicles, the methodological issues are very similar. The baseline would normally be the same for all transit improvements – i.e., the

[1] Herbert Levinson et. al., "Bus Rapid Transit. Volume 1: Case Studies in Bus Rapid Transit," Transit Cooperative Research Program (TCRP) Report 90, Transportation Research Board, 2003.
[2] Levinson, TCRP Report 90, op. cit.
[3] Levinson, TCRP Report 90, op. cit.

continuation of the existing transit system on the corridor. Passengers on the new system – whether rapid bus, BRT or rail – would likely be assigned to a baseline mode based on rider surveys, as discussed below. Monitoring techniques may vary slightly depending on whether the project uses electric or diesel traction, and some modes may have additional sources of leakage such as steel used in rail construction, but the principles should be the same.

In most cases, transit agencies will be the lead organization charged with BRT implementation, usually with a significant city role, particularly if roadway reconstruction or signal priority is required. The institutional structure of transit provision varies widely across the U.S. In some cases, the transit agency may be a city or county department; in others, it may be a special district or a State agency.

## 2.2 Number of Future Projects

There is no comprehensive database of BRT systems, and the Federal Transit Administration's National Transit Database (the standard source for transit ridership, expenditure and operating statistics) does not separate out BRT from other bus services. Partly, this reflects the wide variety of models of BRT in operation and planning at different transit agencies.

The BRT Policy Center lists 56 projects (some of which are in operation) in the United States, several of which include multiple corridors under a single project.[4] For example, the seven planned New York City BRT corridors – the first of which was launched in mid-2008 – are treated as a single project. A 2008 analysis for the Federal Transit Administration, meanwhile, based on interviews with transit agencies, transportation plans and other documents, predicts a minimum of 60 U.S. communities will have BRT by 2017, with many of these operating BRT service on multiple corridors. It concludes: "Over the next ten years, a minimum of three new BRT communities should come on-line per year on average, whether they are self-defined as BRT or not. Additionally, we found that BRT elements are quickly spreading to non-BRT communities and corridors." At least 17 of these could be counted as "BRT heavy" (fully fledged) systems with measures such as signal priority and off-board ticketing.[5]

According to the BRT Policy Center database, the following projects are in operation (note that this is an incomplete list due to delays in updating the database, and some projects may be at an interim phase pending dedicated lanes and other BRT features):

- Pittsburgh Busways, PA (3 projects)
- CityExpress! and CountyExpress!, Honolulu, HI (3 corridors)
- Stockton Boulevard EBus, Sacramento, CA
- El Monte Busway, Los Angeles, CA
- Harbor Freeway HOV/Transitway, Los Angeles, CA
- Metro Rapid, Los Angeles, CA (20 lines)
- Orange Line, Los Angeles, CA

[4] See http://www.gobrt.org/db/login.php.
[5] WestStart-CALSTART, "2008 Bus Rapid Transit Vehicle Demand & Systems Analysis Update," Federal Transit Administration Report No. FTA-CA-26-7074-2008.1. August 2008.

- Silver Streak, Montclair-Los Angeles, CA
- EmX, Eugene-Springfield, OR
- Lynx Lymmo, Orlando, FL
- MAX, Kansas City, MO
- Metro Express, Stockton, CA
- Las Vegas Boulevard North MAX, Las Vegas, NV
- Neighborhood Express, Chicago, IL (4 corridors)
- Rapid, Oakland/East Bay, CA
- RAPID, Phoenix, AZ
- Rapid, San Jose, CA
- Silver Line. Boston, MA
- South Miami-Dade Busway, Miami, FL

## 2.3 Project Development Process and Motivations

There is little research on the relative importance of specific factors that motivate transit agencies and wider communities to implement BRT. In general terms, they are likely to be the same reasons as those behind any transit improvement, such as the desire to serve existing and projected demand; reduce travel times; and promote mode shift away from the private auto. Transit agencies often choose BRT over alternate modes such as light rail following a corridor study; operating and capital costs, capacity and travel times are usually important decision criteria.

AC Transit's $3.2 million San Pablo Rapid service – a lower-cost system operating with signal priority in mixed traffic – provides one example.[6] The service began operation in June 2003, but the project's genesis lies six years earlier in the 1997 San Pablo Avenue Corridor Plan, a collaboration between four cities, AC Transit and other public agencies. This plan set broad goals for the corridor; subsequent implementation steps included:

- A survey and analysis of bus speed and delay data, which concluded that traffic signals accounted for 10-25% of transit delay
- A six-month expert panel, which led to the decision to implement BRT on the corridor
- Detailed planning work and public outreach
- Assembling funding from a combination of county-allocated federal funds and a federal earmark
- 18 months of implementation work, including roadway restriping and signaling

A more complex example is provided by the $90 million Van Ness Avenue proposed BRT project in San Francisco.[7] This was first formally proposed during planning work for the Market/Octavia

[6] Adapted from Federal Transit Administration, "The San Pablo Rapid – BRT Project Evaluation," June 2006.
[7] See http://www.sfcta.org/content/view/306/152/.

neighborhood plan in 2000, and published in the draft 2002 neighborhood plan. Subsequent steps first formalized the proposal in the City's transit planning priorities, and then involved a detailed corridor analysis, public outreach and funding assembly. The project is projected to open in 2012. The specific milestones include:

- Identification of the corridor as a priority in Muni's 2002 conceptual plan, "Vision for Rapid Transit in San Francisco," and the 2004 Countywide Transportation Plan.
- Inclusion of planning and implementation funding in a transportation sales tax measure (approved by voters in 2003).
- A feasibility study adopted in December 2006. This quantified potential travel time savings and ridership gains, assessed impacts on parking and traffic, and developed four alternative designs. It also included public outreach.
- Environmental impact analysis, which began in March 2007 with expected completion in 2009.
- Final design in 2010.
- Construction, which could begin in 2011 for service inauguration in 2012.

Note while these two projects grew out of neighborhood or corridor planning efforts, many other BRT projects may be proposed conceptually but never reach more detailed planning stages. Other projects, meanwhile, may be initiated by the transit agency's own planning work. These two examples provide an indication of the planning and implementation hurdles that need to be overcome, although some simpler projects can be implemented much more rapidly.

## 2.4 Costs and Funding

The heterogeneity of BRT projects – ranging from modest signal priority and customer service improvements to dedicated busways – means that costs vary considerably from one project to another. Figure 1 reports median costs per mile, which range from $1 million for systems in mixed traffic to $7.5 million for busways and $272 million for bus tunnels. In practice, $10 million per mile will be an upper limit for most systems.

Changes in operating costs will vary even more and depend on the extent to which service is expanded to take advantage of new capital facilities. BRT will tend to reduce operating expenses per vehicle and seat mile and thus increase the efficiency of service. Higher speeds mean that fewer vehicles are required to provide the same frequency of service, and BRT often uses large-capacity articulated vehicles. The Euclid Corridor BRT in Cleveland is thus expected to have lower operating costs than the existing transit service on the corridor. However, increased frequencies or the provision of parallel "rapid" and "local" services may increase operating costs in other instances. The marginal operating cost of Metro Rapid service on the Wilshire/Whittier and Ventura corridors in Los Angeles was approximately $12.5 million per year.[8]

[8] Transportation Management and Design, "Los Angeles Metro Rapid Demonstration Program. Final Report," no date.

**Figure 1 Reported Capital Costs of BRT**

| System | Median Capital Cost per Mile | No. of Systems Reporting |
|---|---|---|
| Bus tunnels | $272 million | 2 |
| Busways | $7.5 million | 12 |
| Arterial median busways | $6.6 million | 5 |
| Guided bus operations | $4.7 million | 2 |
| Mixed traffic or curb operations | $1 million | 3 |

Source: TCRP Report 90

Transportation funding is a complex area and it is impossible to discuss potential BRT funding sources fully here. In general, however, BRT projects will draw on three types of capital funding; in practice, funding will often be assembled from a combination of sources:

- **Dedicated federal funding.** The Federal Transit Administration (FTA) has two specific programs where BRT, rail and other transit capital investments may qualify: New Starts and Small Starts. Both have limited resources and competition for available funds is high:
    - New Starts is limited to projects with a capital cost of $75 million or more that operate on separate right-of-ways (including dedicated high-occupancy vehicle lanes). FTA contributes up to 80% of costs.
    - Small Starts is for projects with capital costs of less than $75 million, and has a less rigorous alternatives analysis process. The same federal share of up to 80% applies.
- **Other federal funding.** This is typically allocated through Metropolitan Planning Organizations (MPOs), which are responsible for programming regional transportation investments in metropolitan regions.
- **State and local funding.** Sources include dedicated sales and property taxes; competitive grants such as the San Francisco Bay Area's Transportation Fund for Clean Air; and General Fund revenues.

## 2.5 Emission Reduction Benefits

BRT has the potential to reduce emissions through several pathways:

- **Attracting private auto users to transit.** By replacing private vehicle trips with transit trips, BRT can reduce emissions as transit typically has lower emissions per passenger mile. Ridership increases are generated by several components of the BRT service, such as branding and dedicated rights-of-way, and there are also synergies between the various components (Figure 2). In addition, if this mode shift reduces congestion, there may be further benefits as the remaining vehicles on the road travel at more fuel-efficient speeds.
- **Transit-oriented development.** By promoting compact development within walking distance of transit, BRT can reduce the use of private autos beyond the direct effect of mode shift to transit. Transit-oriented development is associated with more walking and bicycling trips, lower vehicle ownership, and shorter trip distances, and this "multiplier" effect can

account for two to nine times the direct mode shift effect.[9] Some BRT projects have been credited with spurring adjacent development; for example, Boston's Silver Line has generated more than $700 million in new investment.[10] This development and associated emission reductions can often be causally linked to the transit investment, but it is technically very complex to quantify the reductions precisely; it has not been addressed by carbon offset protocols to date.

- **New transit vehicles.** BRT often operates with larger articulated vehicles, which in some cases use alternative fuels. These vehicles may have lower emissions per seat-mile than the previous bus transit service on the corridor.
- **Improving operating efficiency.** Signal priority and computerized dispatch may reduce idling at traffic signals and maintain even headways between buses, helping to reduce transit fuel consumption for a given service level. In some cases, new signal systems installed as part of the BRT project may also reduce delays for other vehicles.

On the other hand, emissions from transit vehicles will increase if service frequencies are enhanced, or if limited-stop or rapid service is overlaid on an existing "local" service. There may also be a rebound effect if new private auto trips are generated following a reduction in congestion due to mode shift to BRT.

**Figure 2 Estimated Ridership Impact of BRT Components**

| Component | Maximum % Ridership Increase |
|---|---|
| Running ways | 20% |
| Stations | 15% |
| Vehicles | 15% |
| Service patterns | 15% |
| Intelligent Transport Systems applications | 10% |
| Synergies between components | 15% |
| Total | 100% |

Source: TCRP Report 118

Greenhouse gas emission reductions from BRT projects have rarely been fully quantified. Transit agencies are often ridership-focused, and so the success of BRT is often measured in increased ridership. Typical ridership gains range from 5-25% over previous local bus service on the corridor, but some systems such as Boston's Silver Line have posted gains of up to 85%.[11]

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9 See, for example: Linda Bailey, Patricia Mokhtarian et al., "The Broader Connection between Public Transportation, Energy Conservation and Greenhouse Gas Reduction." Fairfax, ICF International, 2008; Todd Litman, "Rail Transit In America. A Comprehensive Evaluation of Benefits," Victoria, Victoria Transport Policy Institute, 2006; John Holtzclaw, "Does A Mile In A Car Equal A Mile On A Train? Exploring Public Transit's Effectiveness In Reducing Driving," 2000; Peter Newman and Jeff Kenworthy, "Sustainability and cities: overcoming automobile dependence." Washington, D.C., Island Press, 1999; John Neff. "Substitution Rates Between Transit and Automobile Travel," Association of American Geographers Annual Meeting. Charlotte, NC, 1996.

10 Kittelson & Associates et. al., "Bus Rapid Transit Practioner's Guide," Transit Cooperative Research Program (TCRP) Report 118, Transportation Research Board, 2007.

11 Federal Transit Administration, "Characteristics of Bus Rapid Transit for Decision-Making," Project No. FTA-VA-26-7222-2004.1, August 2004.

Some of these new riders, however, will be drawn from walking, cycling, carpools or other transit systems, or would not have made the trip before. Less data is available on new riders' prior mode of travel, although most do appear to have been diverted from private autos. In addition, trip length data is often lacking, making it difficult to translate ridership gains into reductions in vehicle travel. Selected data and estimates are provided in Figure 3.

**Figure 3 Mode Shift Impacts of Selected Systems**

| City | Facility | Ridership Increase | Prior Mode | BRT Features |
|---|---|---|---|---|
| Charlotte | Independence Blvd. Freeway Busway | 55% | Not available | Running way and stations |
| Cleveland | Euclid Ave. Median Busway | 13% | Not available | Running way and stations<br>Distinctive, easy-to-board vehicles<br>ITS<br>Frequent, all-day service |
| Hartford | New Britain-Hartford Busway | Estimated 20,000 riders/ day at service start | Half of riders expected to be former motorists | Running way and stations<br>ITS |
| Honolulu | City Express! and County Express! | 200% | Not available | Running way and stations<br>Distinctive, easy-to-board vehicles<br>Frequent, all-day service |
| Houston | Express HOV/Busway | 18% to 30% of riders were new | Up to 72% of new riders diverted from private auto | Running way and stations<br>Over-the-road coaches |
| Los Angeles | Metro Rapid, Wilshire-Whittier and Ventura | 26% to 33% | One-third were new riders, one-third existing riders traveling more often, and one-third diverted from other corridors | Mixed traffic<br>Distinctive, easy-to-board vehicles<br>ITS<br>Frequent, all-day service |
| Miami | Miami-South Dade Busway | 50% | Not available | Running way and stations<br>Frequent, all-day service |
| Ottawa | Transitway System | 6% | Not available | Running way and stations<br>ITS<br>Frequent, all-day service |
| Pittsburgh | East Busway | 1,900 new riders when service started | 7-11% of initial ridership had previously used automobiles | Running way and stations<br>Frequent, all-day service |
| Vancouver, BC | | 8,000 new riders when service started | 20% of new riders previously used automobiles, 5% were new trips, and 75% were diverted from other bus lines | Mainly mixed traffic<br>Stations<br>Distinctive, easy-to-board vehicles<br>ITS<br>Frequent, all-day service |

Sources: TCRP Report 90, Tables A-2 and A-11

The most detailed analysis of greenhouse gas emissions reductions from transit is based on the evaluation of early ridership impacts of the Los Angeles Metro Rapid, which showed a 26,800 (42%) increase in weekday ridership on the Wilshire/Whittier corridor and 3,600 (27%) on the Ventura corridor. The analysis estimates a **net reduction in annual $CO_2$ emissions of 9,188 metric tons**[12] – 12,424 metric tons from mode shift, countered by an increase of 3,235 metric tons from additional transit service.[13] This analysis is simplistic in several respects – it assumes that all new riders are transferring from private autos (including carpools) and does not account for any congestion reduction, land-use or operational benefits of BRT. It is also based on early ridership figures that have subsequently increased. However, the study does provide a rough guide to the potential savings from relatively modest investments on a busy urban corridor.

Another example comes from Vancouver, B.C., where an evaluation of the 98 B-Line quantifies **savings of 1,200 metric tons of $CO_2$ per year**. Details of the methodology are not reported, and it is not clear whether this figure is net of emissions from the transit vehicles themselves.[14]

Calculating the cost per ton of emission reductions is even more complex. It requires selection of the project life and discount rate, and the types of costs to include in the analysis. Typically, capital costs only (excluding vehicles) are cited in published research, and operating and vehicle acquisition costs are in any case usually funded from different sources. Specialized vehicles may not be required, and if they are, dedicated sources of funding such as under Section 5309 of the Federal Transit Act may be available. The Los Angeles' Metro Rapid demonstration on the two corridors cost $8.3 million; assuming a 5% interest rate over 10 years (the length of the single-crediting period in the CDM) yields a **cost of $117 per metric ton of $CO_2$ reduced.** Obviously, this would fall if a longer crediting period were used, and rise substantially if vehicle and operating costs were included, as these are far greater than the capital investments. The annual increase in operating costs was $12.5 million, although expected to be less in the long run as service would be consolidated to adjust to new ridership patterns.[15] In Vancouver, B.C. using the same assumptions for crediting period and interest rates and excluding vehicle purchases, the capital cost for the US$30 million 98 B-Line project equates to **$3,238 per metric ton of $CO_2$ reduced.**

Other experience comes from the Clean Development Mechanism, where one BRT project (TransMilenio in Bogotá) is currently registered, three are in the validation process, and several dozen more are expected to be submitted for registration in the next few years. According to Jürg Grütter, the main CDM transportation methodology and project developer, up to 100 CDM BRT projects may be implemented in the medium term.[16] Emission reductions from CDM projects are considerably greater than those in the U.S. (Figure 4). One of the main reasons is that BRT is replacing an extremely inefficient existing fleet of aging, small minibuses that operate in highly congested conditions. In the Bogotá case, mode shift accounted for just 18% of issued CERs, but in the U.S. reduced private auto travel would likely account for the vast majority of the reductions.

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[12] Note that there will also be very minor reductions in $N_2O$ and (unless transit vehicles are powered by natural gas) $CH_4$.
[13] WestStart-CALSTART, "Bus Rapid Transit Ridership Analysis," Federal Transit Administration Report FTA-CA-26-7068-2004.1, June 2005.
[14] Brian Mills, "Bus Rapid Transit in Vancouver: A Review of Experience", TransLink 2004.
[15] Transportation Management and Design, "Los Angeles Metro Rapid Demonstration Program. Final Report," no date.
[16] Jürg Grütter, "CDM Transport Projects Up and Coming," *JIKO Info*, March 2008.

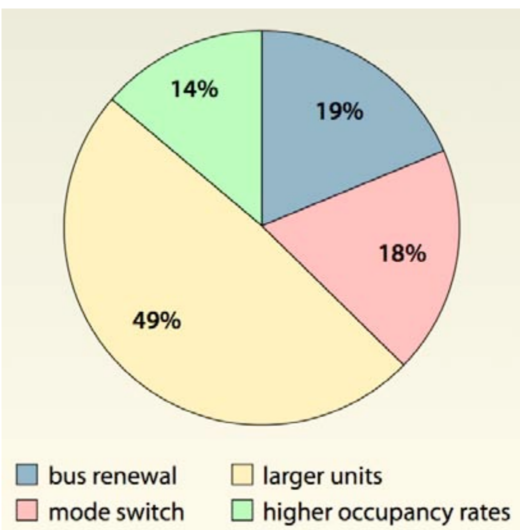
Credited reductions from TransMilenio have been significantly lower than the forecast average of 94,567 CERs per year. This is mainly due to significantly lower-than-expected overall ridership; the percentage of riders switching from private autos has been more in line with expectations. Actual ridership in 2006 was 94 million, compared to the projected 147 million. According to the monitoring report, this is primarily due to operational difficulties in the re-organization of the remaining bus fleet.

**Figure 4 Emission Reductions from CDM BRT Projects**

| Project | Status | Annual Emission Reductions (metric tons/year) |
|---|---|---|
| TransMilenio, Bogotá, Colombia: Phases II to IV | Registered | 2006: 59,020 CERs issued<br>2007: 69,885 CERs issued |
| MIO Cali, Colombia | Undergoing validation | 256,281 (estimated) |
| MEGABUS, Pereira, Colombia | Undergoing validation | 33,393 (estimated) |
| BRT system in Seoul | Undergoing validation | 119,628 (estimated) |
| Insurgentes BRT, Mexico City | Methodology under review | 26,163 (estimated) |

Source: cdm.unfccc.int, accessed October 5, 2008

**Figure 5 Sources of Emission Reductions from TransMilenio**




Source: Grütter 2007. Larger units refers to the use of articulated buses with a capacity of 160 passengers, rather than smaller minibuses. Higher occupancy rates are as compared to the baseline scenario.

## 2.6 Other Environmental Benefits

Greenhouse gas emissions may be one of the smaller environmental benefits from BRT, with the health benefit from reductions in criteria pollutants being far greater (at least when converted to dollar terms). Social and economic benefits may also be considerable; reduced travel times for existing riders are one of the main elements of the cost-effectiveness argument for BRT projects.

# 3 Existing Methodologies

## 3.1 Overview

The Clean Development Mechanism has been the main forum to date for the development of methodologies for BRT projects. One methodology has been adopted and one is under review, but most have been rejected (Figure 6). In general, public transportation methodologies have had a difficult time in the CDM, for which several explanations have been proposed:[17]

- The **complexity** of public transportation methodologies compared to other sectors, for example in developing the baseline, accounting for rebound effects and other leakages, and monitoring mode shifts. This also leads to high transaction costs for methodology development and data collection.
- **Lack of expertise** in transport on the part of the CDM Meth Panel, UNFCCC secretariat and desk reviewers. This has made decisions slow (e.g. as the Meth Panel waits for expert input) and cautious in terms of the types of leakages and upstream emissions that are included. It may also have led to the raising of new issues on resubmittal, which slows down approval and raises transaction costs and risk. For example, the Meth Panel may identify new problems with a methodology after the developer has resolved comments on an earlier draft.
- Potential **inconsistencies** with other sectors. Jürg Grütter argues that transportation projects have to include sources of leakage, such as rebound effects and upstream emissions, that are excluded for simplicity in other sectors such as renewable energy.[18]
- Difficulties in demonstrating **additionality**, although the more immediate barrier is the approval of methodologies. No CDM BRT project to date has been rejected due to concerns over additionality, which is assessed on a project basis. However, concerns over the methods used to determine additionality and the overall "additionality potential" of some project types have been raised during the methodology approval process.
- The relatively small contribution of CER revenue towards **project finance.** This also means that project developers have tended to focus on lower hanging fruit to date, and have not prioritized the development of transportation-sector methodologies.

Some credits from BRT projects in developing countries have been sold on the voluntary market (for example from the first phase of TransMilenio in Bogotá). The lack of transparency of the voluntary carbon market makes it difficult to obtain precise information; however, it is likely that the methodologies used are very similar to those proposed for the CDM.

A range of other methodologies has been used to quantify the impact of BRT on transit ridership and vehicle travel (Figure 7). Typically, these are ex ante analyses used to prioritize and evaluate projects for various funding sources. While the focus is on vehicle travel impacts, these are relatively straightforward to convert to $CO_2$ savings using standard emission factors.

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[17] See, for example: Clean Air Institute, "Report and Strategy to Improve the Effectiveness of CDM to Foster Sustainable Transportation," 2008; Adam Millard-Ball, "The Municipal Mobility Manager: A New Transportation Funding Stream from Carbon Trading." *Transportation Research Record*, 2008; Chris Zegras, "As if Kyoto mattered: The clean development mechanism and transportation " *Energy Policy* 35(10): 5136–5150, 2007; Christian Baatz and Wolfgang Sterk, "Current Status of Transport Projects in the Clean Development Mechanism," Wuppertal Institute, 2007.

[18] Jürg Grütter, quoted in Robin Lancaster, "Caught in the Headlights," *Trading Carbon*, July/August 2008.

**Figure 6** **Proposed CDM Methodologies for Bus Rapid Transit**

| ID | Official Title | Project | Applicability | Reasons for Rejection | Status |
|---|---|---|---|---|---|
| NM0052 | Urban mass transport sector energy efficiency and modal change | TransMilenio, Bogotá | Not specified | No tool for assessing additionality<br>Too project-specific<br>Poor drafting - lack of details and explanations<br>Rebound effects not considered | Rejected Sep. 2004 |
| AM0031 | Methodology for Bus Rapid Transit Projects | TransMilenio, Bogotá | New or expanded BRT systems which partially or fully replace an existing public transport system. Must reduce existing public transport capacities, e.g. through scrapping, permit restrictions or economic instruments. | N/A | Approved July 2006 |
| NM0158 | GHG emission reductions in urban transportation projects that affect specific routes or bus corridors or fleets of buses including where fuel usage is changed | Insurgentes, Mexico City | Corridor-based projects including BRT, but also arterial management (e.g. traffic signal synchronization), congestion pricing, etc. | Lack of causal link between emission reductions and the project. The project draws a "bubble" around the corridor and takes credit for any emission changes.<br>Incomplete leakage calculations, e.g. for rebound effects and construction emissions | Rejected Oct. 2006 |
| NM0229 | Mass Rapid Transit Projects | Insurgentes, Mexico City | Segregated bus lanes (e.g. BRT) or rail-based systems. Must partially replace an existing public transportation system. | Project enhances capacity on a corridor and increases the level of service.<br>Trip lengths may be longer under the project scenario.<br>Project boundary not clearly specified.<br>Induced traffic from BRT-induced development not fully considered | Rejected Nov. 2007 |
| NM0258 | Methodology for Bus Lanes | Insurgentes, Mexico City | New segregated bus lanes which replace existing bus routes operating under mixed traffic conditions.<br>Must replace an existing public transportation system. | N/A | Under consideration |

**Figure 7 Methodologies Used for BRT**

| Methodology | Purpose | Approach | Strengths | Weaknesses |
|---|---|---|---|---|
| AM0031 | CDM | Ex post evaluation. Draws the project boundary around BRT riders, and calculates baseline emissions from rider surveys to determine their prior mode. | Specifically designed for GHG offsets<br>Comprehensive accounting for leakage. | Complexity<br>High monitoring costs<br>Only applicable if the entire trip is undertaken on the BRT system |
| NM0158 | CDM | Ex post evaluation. Uses a "bubble" approach to quantify changes in emissions on the entire corridor. | Applicable to any corridor treatment, including signal retiming and congestion pricing.<br>Quantifies emission savings from reduced congestion. | Rejected by Meth Panel<br>Complexity<br>Difficulties in causal relationship between project and emission reductions<br>High monitoring costs |
| NM0229 and NM0258 | CDM | Similar to AM00031, except uses a passenger-km rather than a passenger-trip approach. Accounts for access trips to and from the BRT station. | Specifically designed for GHG offsets<br>Comprehensive accounting for leakage.<br>More flexible than AM0031 – only part of the trip need be made by BRT. | Rejected (NM0029) or pending (NM0258) in the Meth Panel<br>Complexity<br>High monitoring costs |
| APTA Recommended Practice | Support reporting by U.S. transit agencies | Ex post evaluation. Uses rider surveys to determine prior mode. Determines congestion benefits based on historical trends. Applies a land-use multiplier to quantify benefits of transit in promoting walking and cycling and reducing trip length. | Accounts for congestion and land-use effects of transit, as well as direct mode shift impacts. | Designed for the transit agency level rather than specific projects. |
| New Starts (typical approach) | Competitive funding for New Starts and Small Starts | Ex ante evaluation. For larger projects, uses a regional travel demand model to predict ridership. | Accounts for network effects and rebound due to reduced congestion. | "Black box" modeling approach.<br>Difficult to quantify effects of "soft" factors such as branding and improved reliability. |

### 3.2 Approved CDM Methodology (AM0031)

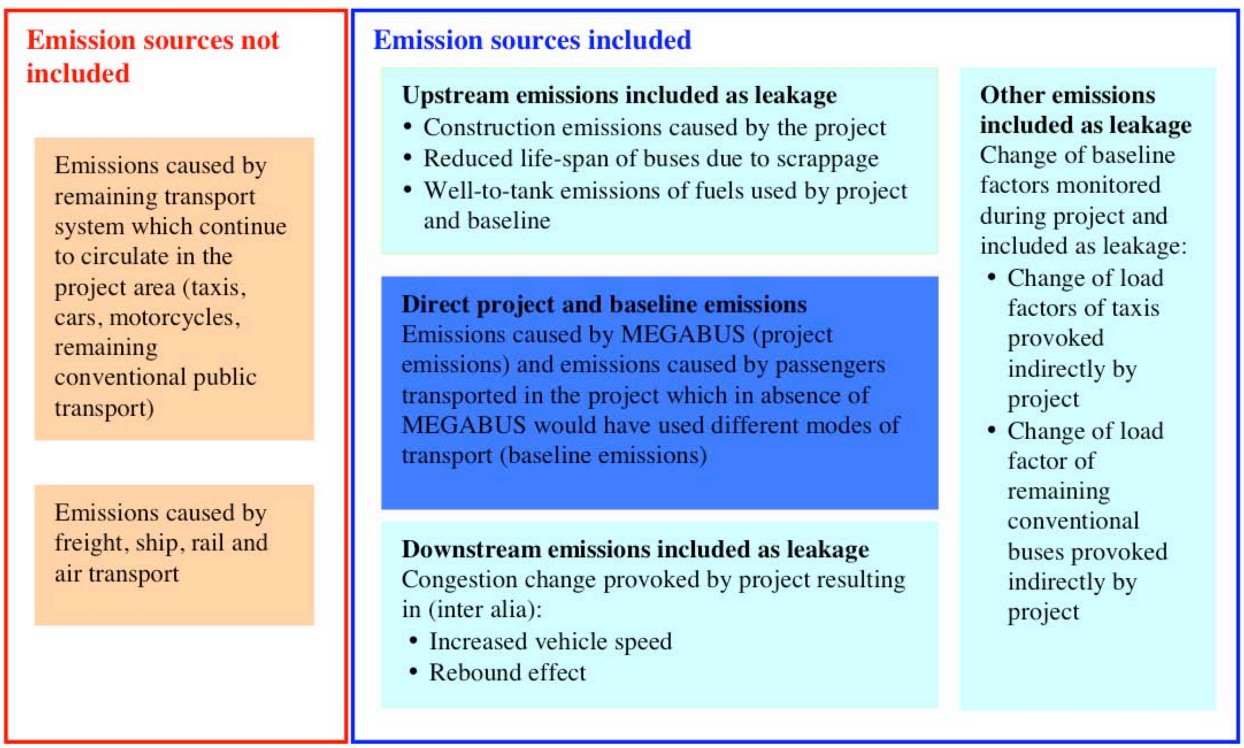
As of October 2008, the Bus Rapid Transit methodology (AM0031) is the only transportation-specific large-scale methodology approved by the Executive Board of the Clean Development Mechanism (CDM). (One biofuels methodology has been approved, AM0047, but this is not transportation-specific.) AM0031 was developed for Phase II of the TransMilenio BRT project in Bogotá, but it can be applied to future BRT projects.

A request for revision for AM0031 is expected to be submitted to UNFCCC shortly, which will propose minor changes in applicability conditions and formulae.

AM0031 uses a passenger- rather than a corridor-based approach. Essentially, it constructs the project boundary around the passenger (Figure 8), and compares emissions per passenger trip based on the modes used in the baseline compared to the project (BRT) scenario. Simply put, the methodology quantifies emission savings from private buses taken out of the market and from mode shift from private vehicles (with mode shift determined from an on-board survey), and deducts emissions from the BRT buses themselves.

Emissions are calculated on a per passenger trip basis, making the methodology inapplicable where BRT only serves one trip segment, rather than the entire trip. (Under AM0031, emissions from dedicated feeder buses are counted as part of the BRT system and are thus treated as project emissions.) This necessitated the development of subsequent BRT methodologies which calculate emission reductions on a per passenger km basis.

**Figure 8 AM0031 Project Boundary**




Source: AM00031, in MEGABUS PDD

Emission reductions are calculated as follows:

- Determine emissions per passenger trip for each vehicle category (e.g. various types of buses, passenger cars, motorcycles, taxis and non-motorized transportation, segmented by fuel type). $CO_2$, $CH_4$ and $N_2O$ emissions are included. Emission factors are calculated ex ante, incorporating an annual technological improvement factor. The methodology provides two options for determining emissions per passenger:
  - Bottom up: based on emissions per km and passengers per km
  - Top down: based on sectoral fuel consumption data
- Determine baseline mode of passenger trips through a bimonthly survey of BRT riders and rider counts from the system operator. The key survey question asks what mode a passenger would have used in the absence of the BRT system. Baseline emissions are then simply the number of trips made by each mode multiplied by emissions per trip. AM0031 goes into considerable detail about the survey methodology. In particular, the maximum permitted margin of error is 5%, and systematic random sampling must be based on the flow of passengers per station per day per hour. The survey must be pre-tested and conducted at bimonthly intervals (to avoid seasonal variation) by a third party.[19]
- Determine project emissions based on fuel purchase records, or emission factors and data on distance driven by transit vehicles.
- Calculate leakages from:
  - Upstream construction emissions, quantified by multiplying the tons of asphalt and cement used by a default emission factors
  - Upstream manufacturing emissions due to the reduced lifespan of buses replaced by the BRT system
  - Savings (negative leakage) from upstream well-to-tank emissions, e.g. from oil extraction, refining and transportation, based on a default 14% multiplier from the literature. This multiplier is applied to the total emissions saved, i.e. baseline minus project and leakage emissions.
  - Changes in occupancy rates on buses and taxis – for example, BRT could lead to lower passenger loads on the remaining transit system. This is monitored through visual surveys.
  - Impacts of reduced congestion, which creates both a negative leakage (rebound effects from reduced congestion) and positive leakage (the remaining vehicles on the road operate more efficiently). This negative leakage is quantified using a standard "rebound" factor of 0.1, derived from the literature.[20] Positive leakage is quantified based on monitoring of speeds and application of speed-dependent emission factors.

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[19] Rider survey methodologies are well established, and detailed guidance on sampling, implementation, etc. has been developed for U.S. transit agencies. See, for example, Transportation Research Board, *TCRP Synthesis 63, On-Board and Intercept Transit Survey Techniques*, 2005.

[20] The exact source of the literature is not discussed in AM0031, but is detailed in subsequent proposed methodologies (e.g. NM0258).

### *3.2.1 Applicability Conditions*

The applicability conditions attached to AM0031 are rather restrictive – particularly the requirement to reduce existing public transportation capacities. This reflects its genesis in a developing country setting, where the replacement of aging microbuses with modern articulated vehicles accounts for a large share of the emissions reductions. The full list of applicability conditions is:

- The project has a clear plan to reduce existing public transport capacities either through scrapping, permit restrictions, economic instruments or other means and replacing them by a BRT system.
- Local regulations do not constrain the establishment or expansion of a BRT system.
- The fuel(s) used in the baseline and/or project case are unblended gasoline, diesel, LNG or CNG. Projects using biofuels either in the baseline or project case are not eligible to use this methodology [although a methodology revision may be proposed].
- The BRT system as well as the baseline public transport system and other public transport options are road-based (the methodology excludes rail, air and water-based systems from analysis).
- The BRT system partially or fully replaces a traditional public transport system in a given city. The methodology cannot be used for BRT systems in areas where currently no public transport is available.
- The most reasonable baseline scenario is a continuation of the current public transport system.

## 3.3 Other CDM Methodologies

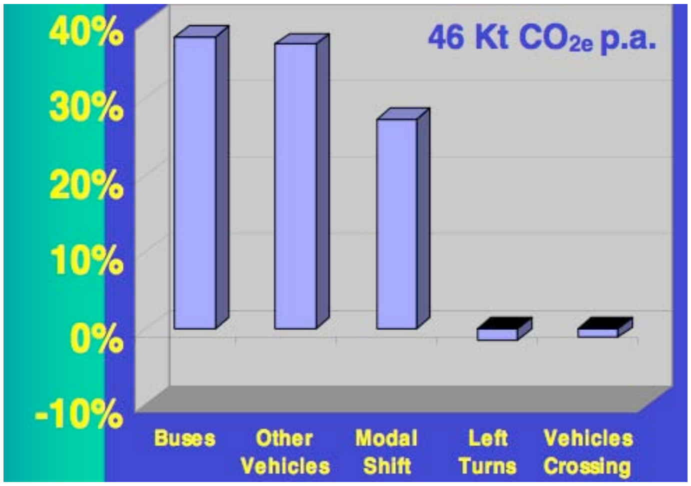
[Note that NM-prefixed methodologies may have been rejected by the CDM Executive Board, or a decision may still be pending. AM-prefixed methodologies have been approved.]

### *3.3.1 NM0158 Corridor Methodology*

An alternative methodological approach, typified by the initial Insurgentes (Mexico City) methodology (NM0158), has a radically different conceptual approach. While it was rejected by the CDM Executive Board, it can still be considered a valid approach – especially for transit projects that incorporate a major arterial management component. This methodology has been used to sell emission reductions on the voluntary market from the Insurgentes project.

Rather than the passengers changing modes, it defines the project boundary as the BRT corridor. It draws a "bubble" around the corridor and its intersections, and compares observed emissions to a counterfactual based on traffic growth in the metropolitan area as a whole. While designed for the Insurgentes BRT project, the methodology is broad in nature; it can be applied to any corridor project including signal retiming or congestion pricing. Indeed, project proponents projected that nearly 40% of the emission reductions would be gained from smoother traffic flow and reduced idling from private vehicles, rather than from mode shift or fuel-efficient buses (Figure 9).

**Figure 9 Projected Emissions Reductions from Insurgentes BRT**




Source: Energy Efficiency in the Transport Sector, presentation by John Rogers, 12/8/05

Given that it was not approved, this methodology is not discussed in detail in this paper. However, it is far more complicated than the Bogotá methodology. Virtually every conceivable impact of the project is quantified, including delays to cross-traffic from BRT signal priority and increases in trip length due to left-turn prohibitions on the BRT corridor. The methodology includes 39 formulae and requires 32 types of data, derived from traffic counts, on-board surveys and floating car speed surveys. It also outlines an elaborate optimization process to determine sample sizes; data are to be collected up until the point that data collection costs outweigh the value of the additional emissions reductions gained.

The main reason for rejection by the Executive Board related to the corridor-wide "bubble" approach. In one reviewer's opinion, this would attribute to the project any changes affecting traffic on the route, e.g. from new development projects:

> The methodology has a core conceptual problem due to the bubble created which is the lack of a clear link between emission reductions measured and the project activity i.e. measured emission reductions might well be a result of activities not related to the project or due to force majeur…While being very elaborate on sometimes marginal issues the core aspects are thus questionable and the methodological approach does not ensure that emission reductions are due to the project activity.

### *3.3.2 Bus Lane Methodology (NM0229 and NM0258)*

Both NM0229 and NM0258 are based on the AM0031 Bogotá methodology, but are designed for transit projects that also include an access trip, i.e. only use the BRT facility for part of the trip. In contrast, AM0031 included the entire transit trip, including dedicated feeder bus service which is considered part of the BRT project. Emissions are thus calculated on a passenger km rather than a passenger trip basis. NM0229 also sought to broaden the applicability conditions to allow rail projects.

These proposed methodologies therefore pay greater attention to the access trip and trip distances. The initial rider survey asks about origins and destinations, and the access mode used to get to and from the BRT stop.

The methodologies also include several simplifications as compared to AM0031. For example, they exclude $N_2O$ and (unless gaseous fuels are used) $CH_4$ emissions.

## 3.4 Non-Offset Methodologies

### *3.4.1 American Public Transportation Association*

The American Public Transportation Association (APTA) is currently finalizing a recommended practice for quantifying greenhouse gas emissions and emission reductions from transit. This is intended for use at the transit agency or regional level, rather than the project level, for example in order to support reporting to The Climate Registry and similar organizations.

However, the broad principles can also be used to inform a project-level protocol for BRT or other transit improvements. In general, the guidance is consistent with AM0031 (as well as The Climate Registry General Reporting Protocol): baseline emissions are calculated based on a rider survey asking what mode riders would use in the absence of transit, and emission factors for various modes. Project emissions are taken from National Transit Database data on transit fuel consumption.

The APTA guidance does incorporate various extensions to AM0031 that might be incorporated into a project-specific protocol:

- Accounting for changes in vehicle ownership. Under AM0031, any respondent who states that they would not have made the trip in the absence of the project is assigned zero baseline emissions. However, this ignores the long-run effect of BRT on vehicle ownership. The APTA guidance suggests a second survey question asking if the household has a vehicle available for that trip, and if not, if they would buy a car if transit service were to cease.
- Accounting more fully for congestion benefits. AM0031 does include congestion benefits, but only to offset other elements of leakage – if total leakage is negative, it is counted as zero.
- Accounting for development benefits. As discussed in Section 2.5, transit can produce emission reductions over and above the direct mode shift effects through promoting compact development, which reduces travel distances and promotes walking and cycling. These land-use effects can be two to nine times greater than the direct mode shift effect. While this "transit multiplier" is difficult to incorporate at a project level, it may provide a justification for simplifying or ignoring some potential leakages.

### *3.4.2 Specific Project Evaluations*

Planning work for BRT projects usually includes a detailed ex ante analysis of ridership and (for larger projects) traffic impacts. The resultant estimates of changes in vehicle travel (VMT) can be converted to greenhouse gas emissions through the use of standard emission factors.

For small projects, a recent guidebook recommends using elasticities for travel time, service frequencies and fares to estimate ridership increases. For larger projects, four-step models may be appropriate.[21] These models predict mode choice and assign traffic across the road network in a county or region, based on travel times and other factors, and are better suited to analyzing larger investments in transportation infrastructure.

Large BRT projects are often required to complete ex ante evaluations of their environmental impacts, particularly in states such as California that have requirements above and beyond federal law. These usually include an analysis of greenhouse gas impacts, based on the four-step traffic modeling studies described above.

Ex post evaluations are more rare, although several have been conducted for recent BRT projects, for example those funded under a FTA demonstration program.[22] However, these have tended to focus on ridership impacts, operational issues and costs. Few if any have directly addressed greenhouse gas emission reductions.

### *3.4.3 Global Environment Facility*

Several BRT projects in developing countries are currently being funded through the Global Environmental Facility (GEF). The GEF is an independent international organization, although projects are managed by three implementing agencies: the United Nations Environment Programme, the United Nations Development Programme, and the World Bank. Funding agreements generally require ex post monitoring of greenhouse gas benefits, as well as an ex ante estimate of the emission reduction potential. However, a standardized approach has yet to be agreed, and so these estimates and monitoring are currently conducted on a case-by-case basis.

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[21] TCRP Report 118, op. cit.

[22] See, for example, Transportation Management and Design, "Los Angeles Metro Rapid Demonstration Program. Final Report," no date, available at: http://www.fta.dot.gov/assistance/technology/research_4301.html; and other reports available at: http://www.fta.dot.gov/assistance/technology/research_4238.html.

# 4 Issues for a U.S. Methodology

This section builds off the information and analysis presented in the previous sections in order to address some key issues for the development of a U.S. methodology for BRT or other corridor-based transit improvements.

## 4.1 Implications of Cap-and-Trade

The Western Climate Initiative proposes to include transportation via an upstream cap from 2015. Upstream cap-and-trade for transportation was also included in most federal legislative proposals for cap-and-trade in the last Congress (e.g. Lieberman-Warner), that are likely to be the basis for future legislation. A cap-and-trade system that extends to the transportation sector would preclude the possibility of any transportation-sector offsets in order to avoid double counting (once through the offset, and once as refiners or other regulated entities need to surrender fewer allowances due to lower gasoline demand).[23]

Note that a widely accepted BRT "offset" protocol would still have value under cap-and-trade. For example, it might be used to direct competitive grant funding for $CO_2$ reduction projects in capped sectors, or for Joint Implementation-style programs where regulated entities seek to fund alternative emission reduction projects.

The time taken to develop a BRT project varies considerably depending on the degree of capital investment, funding availability and political constraints. A system with modest priority measures that does not require roadway reconstruction might be implemented in a year or two, while more extensive systems may need five to ten years from planning to implementation. The main hurdles are usually the need to assemble funding, and time to conduct and fund planning studies and environmental review (see also Section 2.3). If an upstream cap-and-trade system begins in 2015, there may only be a short window for BRT systems to earn emission reduction credits.

## 4.2 Ownership and Double Counting

The logical owner of the emission reduction credits would be the transit agency or local government. This has been the approach taken under the CDM, and also in analogous methodologies on the voluntary market. For example, credits from arterial management in Portland, Oregon (a Climate Trust project) accrue to the City of Portland, not the individual drivers.

In theory, there may be scope for double counting with individual bus riders. Indeed, this concern has hampered the approval of several CDM methodologies – notably in biofuels and the introduction of energy-efficiency appliances, where the Executive Board has suggested that consumers should be the beneficiaries. In practice, however, it is difficult to see how it would be worth the while of individual riders to claim emission reduction credits, amounting to less than a penny per trip. Philosophically, transit agency ownership can be justified if the offset revenue is seen as an alternative to higher fares.

More relevant are concerns with double counting with other potential offset projects. For bus fleet efficiency, this is relatively easily resolved since the precise vehicles involved will usually be known; double counting can be prevented provided the same registry is used for both BRT and fleet

[23] For a discussion, see Adam Millard-Ball, "Cap-and-Trade: Five Implications for Transportation Planners," accepted for *Journal of the Transportation Research Board* and for Transportation Research Board Annual Meeting, January 2009.

efficiency offset projects. Since bus efficiency would likely be captured within a BRT methodology, any issued credits from a bus efficiency project could simply be deducted from the BRT project (although in practice, an agency would presumably not purse both offset projects simultaneously). However, there may be other projects where complementary policies work together with BRT to reduce travel demand. For example, emissions reductions from a transit rider might conceivably be claimed by any of the following, in addition to the transit agency:

- A rideshare agency or Transportation Management Association (through information and marketing programs)
- An employer or developer (e.g. through subsidized transit pass programs)
- A car-sharing provider (through encouraging its members to shift to transit)
- A funding partner, such as the Federal Transit Administration, Metropolitan Planning Organization or a local sales tax agency (through the BRT project itself)
- A municipality (through investments in transit infrastructure or signal priority, or transit-oriented development)

While a theoretical concern, the issue is hypothetical in the absence of any (to the author's knowledge) widely applied methodologies. Double counting might best be addressed in the context of any subsequent methodologies, and/or treated on a "first come, first served" basis.

## 4.3 Additionality

CDM transportation projects have tended to use barrier analysis rather than investment additionality (e.g. calculating the Internal Rate of Return). This is appropriate given that most implementing agencies are public sector bodies and are not normally driven by IRR and similar criteria. However, as with any type of barrier analysis, it is inherently a more qualitative process. BRT projects are driven by multiple criteria and bring congestion mitigation and air quality benefits, and so ultimately there is no clear threshold over which additionality is certain.

Some of the barriers that offset funding may be able to help overcome include:

- **Political resistance.** In the CDM, one of the main barriers used to demonstrate additionality is the resistance of existing transport operators, who have sometimes resorted to demonstrations and burning buses to protest against BRT. In the U.S., resident opposition to loss of mixed-flow travel lanes and parking are significant barriers, which certification as an offset might help to overcome through reframing the project as a greenhouse gas emissions project, or through providing funding for compensatory community benefits or other mitigations. For example, in Berkeley, AC Transit's proposed BRT corridor has been hampered by protests over dedicated bus lanes,[24] even though the city has a voter-approved target of reducing greenhouse gas emissions by 80% by 2050. Measure KK, an unsuccessful measure on the Berkeley ballot for November 2008, would have added a major hurdle to future BRT projects by requiring voter approval for any bus or high-occupancy vehicle lanes.

[24] See, for example, San Francisco Chronicle, "Berkeley rapid bus plan faces uphill battle," July 7, 2008.

- **Financial gaps.** Large-scale transportation projects typically take many years to assemble funding from multiple sources. Even if federal funding is available, a substantial local match is usually required which can delay or stall a project altogether. Inclusion in a regional transportation plan ensures eligibility for various funding sources, but does not guarantee that funds will materialize. Offset funding may be able to fill a gap, although given the wide differences between projects it is difficult to draw general conclusions.

Note that there are no specific regulations requiring BRT, and so regulatory additionality is not an issue. In California, BRT is not specifically included in the draft scoping plan from the California Air Resources Board (CARB), although it may be captured to some extent in the "regional targets" category, which follows the approach set out in Senate Bill 375. Under this legislation, targets for passenger vehicle emissions are to be developed by CARB by 2010 for each metropolitan region in California. The manner in which the targets are to be achieved is left to the discretion of each region, which must develop a Sustainable Communities Strategy. These strategies and the regional transportation may or may not include BRT, and in any case its inclusion is no guarantee of implementation due to funding shortfalls, political constraints or other barriers. Thus, there are no clear implications for additionality – either in California or in any other state that may adopt similar legislation.

Technically, BRT generally uses established technology. However, staff in most transit agencies and local jurisdictions has little experience with BRT implementation. In some cases, a "first of its kind" test (a more restrictive version of a common practice test) may therefore be warranted. Under the CDM, additionality can be demonstrated if no similar project has previously been implemented in a certain geographic area. For a U.S. application of this test, a key issue would be defining the geographic area – for example a metropolitan region or state, or the entire nation (which would render the test moot). "Fully fledged" BRT might also be considered for a first-of-a-kind test even if simpler Rapid Bus projects have already been implemented in a given state or region.

It may be possible to develop a top-down approach through specifying key criteria or performance standards that a BRT project must meet in order to be considered additional. However, this approach has not been used to date, and it is difficult to envision what the criteria would be. The barriers to BRT projects vary considerably – financial, political and technical – depending on the type of project and its context.

Methodologies for transportation in the CDM to date have used the 48(a) approach (actual or historical emissions). The 48(c) benchmarking approach, which uses a performance standard, has not been attempted for transportation mode shift projects, to the author's knowledge. One option may be to develop a benchmark based on emissions per passenger trip or passenger mile. However, it is unclear how this would work in practice, and the concept would require further work to implement. It would also be difficult to take into account impacts on trip generation and induced demand using a benchmarking approach.

## 4.4 Project Boundary

There are two broad options for drawing the project boundary for a Bus Rapid Transit project:

- **Passenger based.** This option, used in AM0031, draws the project boundary around BRT riders, and compares emissions from BRT and access trips against the riders' modes in the baseline scenario. This is probably the simpler alternative.
- **Corridor based.** This option draws the project boundary around the BRT corridor, and would measure traffic volumes and emissions from all vehicles on the corridor. This approach was used in the (rejected) NM0158 methodology. It allows for the capture of broader impacts of BRT on congestion, traffic flow and transit-oriented development, and avoids relying on a survey in which passengers may be unsure of their alternative mode. However, a corridor approach may include some emission changes that are not directly connected to implementation of BRT, and there may be difficult questions of corridor definition (e.g. the extent to which parallel streets are included).

## 4.5 Baseline Selection

Determining the project baseline requires the construction of a counterfactual scenario regarding emissions in the absence of the BRT project. Typically, the baseline scenario consists of the current transportation system. This is the simplest approach, but it may considerably underestimate baseline emissions. In many cases, BRT will be an alternative to other transportation investments to relieve congestion, such as increased roadway capacity along the same corridor. While these roadways may have short-term emissions benefits via reduced congestion, their long-term effects in encouraging greater automobile use and auto-dependent land-use patterns will usually increase emissions. Thus, a baseline scenario that ignores highway expansion may underestimate baseline emissions.

This alternative baseline will usually be difficult to justify with sufficient confidence. The exception is where a corridor study evaluates several alternatives, such as BRT and high-occupancy vehicle lanes or general-purpose lanes, for meeting travel demand and reducing congestion. On urban arterials, in contrast, the continuation of the existing transportation system may be the most reasonable baseline.

A third approach is to use a control corridor as the baseline. Traffic and transit rider volumes and vehicle speeds could be monitored on a similar corridor in another part of the city or region, where no BRT investment is taking place. The assumption would then be that percentage changes in emissions or transit mode share on the BRT corridor under the baseline scenario would be the same as those on the control corridor. This control group approach has yet to be adopted for any CDM transportation methodology, but is currently being considered by the Meth Panel as part of NM0279 for transit-oriented development.

## 4.6 Monitoring

Monitoring requirements for the approved CDM methodology, AM00031, are rather involved and complicated. However, the main complexities relate to leakage, which as discussed in Section 4.7 may be able to be simplified considerably in the context of the U.S. voluntary market.

Figure 10 shows data requirements for AM0031, and potential sources if it were to be applied in a U.S. context. The figure also indicates elements that could be eliminated via a potential simpler approach. With a simplified version of the methodology that excludes the majority of potential leakages, almost all data should be available from published sources or a transit agency's own records. The exception is the passenger survey that is required to assess the mode that passengers would have used in the absence of BRT, although many transit agencies do conduct these on a routine basis for service planning purposes.

Figure 10 also provides a qualitative assessment of the uncertainty of each variable or parameter. Most inputs are of low uncertainty, as they either rely on fuel purchasing or mileage records, or because the desired sampling error can be achieved simply by increasing the sample size. For many inputs, such as emission factors, there is a clear tradeoff between lower uncertainty (for example, by using regional- or corridor-specific data) and lower transaction costs through minimizing data collection. The main "high uncertainty" inputs relate to leakage, particularly from congestion effects (which may be positive or negative) and construction emissions.

**Figure 10 Data Requirements for AM0031**

| AM0031 ID | Data Point | Potential Source in U.S. Context | Required for potential simplified methodology? | Level of Uncertainty |
|---|---|---|---|---|
| 1 | Total fuel consumption for BRT fleet (option A) | Transit agencies must report fuel consumption to National Transit Database (NTD), although BRT services would need to be disaggregated | Yes | Low. Obtained from fuel consumption records and validated by mileage driven |
| 2 | Fuel efficiency of BRT vehicles (option B) | Transit agency records | No | Low-medium, depending on availability of vehicle-specific emission factors |
| 3 | Distance driven by BRT vehicles (option B) | Transit agency records | No | Low. Calculated directly from records of service provision. |
| 4 | Number of vehicles by fuel type | Use State average from DMV, or regional source if available | Yes | Low-medium, depending on whether baseline vehicles differ from state or regional fleet |
| 5 | Fuel efficiency of each vehicle type | Use defaults from State or regional figures or US EPA | Yes | Medium. Overall emission factors may be well established, but BRT usually displaces (less fuel-efficient) peak period trips |
| 6 | Total distance driven by buses | Transit agency records based on NTD reporting | Yes | Low. Calculated directly from records of service provision |
| 7 | Bus ridership prior to BRT | Transit agency records based on NTD reporting | Yes | Depends on measurement system used by transit agency |
| 8 | Bus load factors | Transit agency records based on NTD reporting, or line-by-line monitoring | Yes | Depends on measurement system used by transit agency |
| 9 | Average trip distances | Passenger survey or data from Metropolitan Planning Organization (MPO) | No | Medium, depending on availability of estimates from MPO |

| AM0031 ID | Data Point | Potential Source in U.S. Context | Required for potential simplified methodology? | Level of Uncertainty |
|---|---|---|---|---|
| 11 | BRT ridership | Rider counts or farebox data | Yes | Low, assuming that sufficient counts are conducted via robust sampling procedure |
| 12 | Mode that BRT passengers would have used | Rider survey | Yes | Low in short term, assuming that sufficient counts are conducted via robust sampling procedure. Medium in longer-term, as riders may not be able to meaningfully assess alternative mode |
| 13 | Policies that would affect baseline emissions | Unlikely to be relevant | No | Depends. |
| 14 | Amount of cement used in construction | Final engineering design | No | Low, but emission factors may be subject to more uncertainty. |
| 15 | Amount of asphalt used in construction | Final engineering design | No | Low, but emission factors may be subject to more uncertainty |
| 17 | Buses scrapped by project | N/A (see leakage section below) | No | N/A |
| 18 | Average age of retired vehicles | N/A (see leakage section below) | No | N/A |
| 19 | Average age of scrapped buses | N/A (see leakage section below) | No | N/A |
| 20 | Load factors on non-BRT fleet | Transit agency records based on NTD reporting, or line-by-line monitoring | No | Low-medium, depending on monitoring procedure |
| 21 | Number of non-BRT buses operating | Transit agency records based on NTD reporting | No | Low |
| 22 | Share of road space used by public transport in baseline | Can be estimated based on % of vehicles on corridor accounted for by buses | No | Medium-high, depending on procedure used |
| 23 | Amount of road space before and after project | Based on number of lanes and length of roadways | No | Low. Calculated directly |
| 24 | Number of daily car trips | Vehicle counts | No | Low, assuming robust sampling procedure |
| 25 | Average passenger car speed before and after project | Based on model outputs, e.g. the regional travel demand models typically used for BRT planning | No | Low-medium, depending on data collection procedure. Conversion into emission factors medium-high |

## 4.7 Leakage

Incorporating leakage has been the primary factor behind the high complexity of BRT methodologies to date in the CDM. In retrospect, the CDM approach may have been overly exhaustive, and a U.S. methodology for the market may be able to be simplified considerably for several reasons:

- In practice, leakage to date has been zero in the Bogotá project (or more precisely, leakage has been positive and thus a zero value is applied).
- Several of the sources of leakage are not included in methodologies in other sectors, particularly upstream emissions from cement and asphalt, and the reduced lifespan of existing equipment. To the extent that these are excluded from other CCAR protocols, they might be excluded from a BRT protocol.
- Reduced lifespan (scrappage) of existing buses is primarily an issue for the developing world, where private microbuses are displaced by new BRT systems. In U.S. transit agencies, buses would simply be reassigned to other routes.

Figure 11 indicates potential leakages that could be considered in a new methodology. The most complex are likely to be impacts on congestion, the direction of which will vary with project type and local conditions. A BRT project that incorporates extensive priority measures such as dedicated lanes, and that reduces capacity for private autos, may in some cases increase congestion. Projects that use more modest priority measures and upgrade traffic signals on a corridor may reduce congestion. BRT may also help to reduce congestion through setting a lowest acceptable travel speed. In other words, faster transit may reduce auto drivers' tolerance for congestion, ensuring that a new equilibrium following increased transit speeds will be less congested than the original situation.

Moreover, it is not necessarily evident whether reductions in congestion will increase or decrease emissions; this will depend on the extent to which idling is reduced, and on latent demand for vehicle travel in the corridor.

Note that one of the main congestion benefits of BRT in developing countries is through removing small, private buses from the roads; thus, the overall impacts of BRT will be smaller in the U.S.

## 4.8 Permanence

Emission reductions from Bus Rapid Transit are permanent. As with any project that reduces fossil fuel consumption, there is no risk of reversals in that these emissions would be subsequently released into the atmosphere.

In the transportation context, there may be some confusion with the term "permanence," as this is often used to refer to the permanence of modal shifts. For example, there is some uncertainty whether travel behavior changes prompted by the introduction of BRT or demand management measures are permanent, or whether riders subsequently revert back to previous modes of travel. This issue can best be addressed through project monitoring of ridership levels, and is more properly termed "years of effectiveness" rather than "permanence." However, even if the *mode shift* is temporary, the *emission reductions* are permanent – emissions avoided during a program's first year are not released to the atmosphere, even if riders subsequently shift back to single-occupant vehicles.

**Figure 11 Potential Leakage from BRT**

| Leakage | Description | Direction* | Comments |
|---|---|---|---|
| Upstream well-to-tank emissions | Oil extraction, refining and transportation | Positive | Well-to-tank emissions are about 14% of combustion emissions, according to AM00031 |
| BRT construction | Cement, asphalt and steel used in roadway and station construction Traffic disruption from construction | Negative | |
| Vehicle manufacture | Bus manufacture | Negative | |
| Reduced loads on other transit lines | BRT may shift demand from other transit routes | Negative | Will be negligible if frequencies on other lines are adapted following BRT implementation |
| Induced transit trips | Some BRT trips would not have been made in the baseline scenario | N/A | Captured through assuming zero baseline emissions from passengers who would not have made the trip in the absence of BRT. |
| Induced private auto trips | New vehicle trips may "backfill" space vacated via mode shift, in response to reduced travel times | Depends | |
| Changes in congestion | Changes in congestion will affect fuel efficiency of private autos | Depends | |
| Other household members | If one household member switches to BRT, the vehicle may be used by another household member | Negative | |
| Land-use changes | BRT may spur transit-oriented development which reduces private auto use | Positive | |
| Midday trips | Use of transit for commute trips reduces auto use for trips during the working day | Positive | |
| Vehicle ownership | Availability of BRT may reduce household auto ownership and thus have a broader impact on vehicle travel. BRT may also enable reductions in required parking for new development. | Positive | Vehicle ownership is highly correlated with transit availability, although effects may be difficult to quantify at the project level |

* Positive leakage indicates that additional emission reductions are achieved outside of the project boundary. Negative leakage indicates that emission reductions from the project are countered by some increased emissions outside of the project boundary.

# 5 Emission Reduction Opportunities

This section provides order-of-magnitude estimates of the emission reductions potential of Bus Rapid Transit projects in the U.S. It is based on evaluations of U.S. BRT projects to date, particularly the WestStart-CALSTART analysis of Los Angeles Metro Rapid, together with estimates of potential BRT investment growth and ridership.

Several transit agencies and members of the American Public Transportation Association have expressed interest in a BRT protocol and other opportunities to become an offset provider. However, this interest is largely conceptual to date; there has been little detailed work by transit agencies to quantify the monetary potential or evaluate which projects might be eligible for offset funding. The only detailed analysis to the author's knowledge has been commissioned by New York Metropolitan Transit Authority from consulting firm Booz Allen Hamilton, and is expected in Spring 2009. King County Metro in Washington state is generating offsets via its membership in the Chicago Climate Exchange, but these are not BRT-specific. Carbon offset project developers, meanwhile, have largely steered clear of the transportation sector to date, partly due to the perceived complexity but also because other sectors have offered lower-hanging fruit.

Figure 12 presents estimates of new ridership and capital costs from the Federal Transit Administration's "Small Starts" funding program (discussed in Section 2.3). It converts these to an order-of-magnitude cost per ton by using the figures presented in Section 2.5 for the emission reduction per new rider on the Los Angeles Metro Rapid (0.3 metric tons/year per new rider). These projects may differ from Metro Rapid in significant ways; the aim is not to provide precise estimates but to give a sense of the order-of-magnitude reductions. With the exception of the Metro Rapid System Gap Closure project, all projects are extremely expensive, at more than $8,500 per ton and sometimes considerably more. On the other hand, projects usually beat their ridership expectations (15 out of 17 rail and BRT projects, according to a forthcoming analysis by Reconnecting America).[25]

Projects seeking federal funding may be significantly more capital-intensive than BRT projects in general; more modest projects may be funded via local sources. These estimates should therefore not be taken as representative of all planned BRT projects. However, in general – when measured by greenhouse gas reduction benefits alone – BRT is likely to be an expensive option compared to abatement opportunities in other sectors. Estimates of the cost per ton of emission reductions from transit expansions overall (bus, BRT and rail) tend to lie in the hundreds of dollars per ton range.

As discussed in Section 2.2, a minimum of 60 communities in the U.S. are expected to have developed BRT systems by 2017. Assuming that the mean emission reductions per corridor presented in Figure 12 is representative of these systems, and that an average of three BRT corridors are developed per community, **total emission reductions from BRT might amount to 250,000 metric tons per year.** This is clearly a highly imprecise estimate, but gives a sense of the order of magnitude that might be expected.

**It is important to note that these cost-per-ton and emission reduction estimates refer only to emission reductions that might reasonably be expected to be claimed via a carbon offset protocol.** Actual cost per ton is likely to be lower by perhaps a factor of 15 or more for several

[25] Reconnecting America, "Destinations Matter: Building Transit Success," forthcoming.

reasons. First, the nature of the offset market and the likely advent of an upstream cap-and-trade system for transportation limits the length of the expected crediting period. The estimates here assume a ten-year crediting period, even though a BRT project may have a 40-year or longer useful life. Second, these estimates exclude second-order emission reductions from congestion mitigation and transit-oriented development, which are likely to be more difficult to quantify precisely.

The actual technical and cost-effective potential is extremely difficult to quantify, and no estimates are available to the author's knowledge, although a forthcoming Urban Land Institute book, *Moving Cooler*, is expected to estimate the potential for expansion of urban fixed guideways (which would include BRT). The main problems in estimating the potential include:

- The "technical potential" is not a particularly useful concept. In theory, BRT elements such as signal priority and fare prepayment could be applied to all transit routes in the nation. However, this is unlikely to be an appropriate use of resources, and impacts on other modes (i.e., private autos) from transit priority measures may be unwarranted given ridership on some lightly used lines.
- The cost-effective potential (when including co-benefits) is driven largely by travel time savings and current ridership levels. These are highly corridor specific, and difficult to estimate with any reasonable certainty at the national aggregate level.
- BRT is usually appropriate on corridors that have relatively high ridership already. However, national transit statistics are aggregated at the agency level; no corridor-level information is readily available.
- Even if the number of potential corridors could be identified, BRT may not be the appropriate investment; light rail may be a preferred option for capacity or other reasons.

**Figure 12 Estimated Emissions Impacts of Selected Proposed BRT Projects**

| Proposed Project | Capital Cost (including vehicles where applicable) | Projected New Daily Riders | Order-of-Magnitude $CO_2$ Reduction (metric tons/yr)* | Capital Cost Per Metric Ton** |
|---|---|---|---|---|
| Mountain Links BRT, Flagstaff, AZ | $10.4 million | 500 | 151 | $8,913 |
| Livermore - Amador Route 10 BRT, Livermore, CA | $21.7 million | 900 | 272 | $10,331 |
| Metro Rapid Bus System Gap Closure, Los Angeles, CA | $25.7 million | 40,000 | 12,089 | $275 |
| E Street Corridor sbX BRT San Bernardino, CA | $163.4 million | 800 | 242 | $87,518 |
| Van Ness Avenue Bus Rapid Transit, San Francisco, CA | $87.6 million | 1,600 | 484 | $23,460 |
| Mason Corridor BRT Fort Collins, CO | $74.2 million | 400 | 121 | $79,484 |
| South Corridor BRT Grand Rapids, MI | $36.7 million | 1,300 | 393 | $12,097 |
| Troost Corridor BRT Kansas City, MO | $30.7 million | 1,200 | 363 | $10,962 |
| Pioneer Parkway EmX BRT Springfield, OR | $37.0 million | 450 | 136 | $35,231 |
| Bellevue – Redmond BRT King County, WA | $27.0 million | 300 | 91 | $38,564 |
| **Median** | **$33.7 million** | **850** | **257** | **$17,779** |
| **Mean** | **$51.4 million** | **4,745** | **1,434** | **$30,684** |

Source of cost and ridership data: Federal Transit Administration (2008), “Annual Report on Funding Recommendations. Proposed Allocations of Funds for Fiscal Year 2009. New Starts, Small Starts, Alternative Transportation in Parks and Public Lands.” Excludes projects without estimates of new ridership
*$CO_2$ reduction estimates assume same reduction per new rider as the Los Angeles Metro Rapid, using estimates from Calstart-Weststart, 2005. This is calculated as emission reductions from mode shift net of emission increases from service enhancements. Note that since the Metro Rapid demonstration project used standard vehicles, no bus efficiency improvements are captured in this figure.
**Cost per ton assumes a 10-year project life and 5% interest rate.