# Public Comments on the Purple Line AA/DEIS

Submission by World Resources Institute, 10 G Street NE, Washington DC 20002

## Key Findings and Recommendations

**Findings:**

1) WRI's sensitivity analysis of estimated costs and ridership for the various Purple Line options finds that Medium Investment Bus Rapid Transit (BRT) is the most cost-effective and lowest-risk build alternative.

2) WRI's assessment of carbon dioxide ($CO_2$) emissions projections confirms that Medium and High Investment BRT are the only alternatives likely to reduce $CO_2$ emissions from the No Build scenario.

3) Despite its public popularity, WRI concludes that the Light Rail Transit (LRT) option is less robust, as our analysis shows that it will increase $CO_2$ emissions and very likely overrun current cost projections.

**Recommendations:**

1) WRI supports a transit investment in the proposed east-west corridor, and argues that the No Build and Transportation System Management alternatives are inadequate to address the congestion problem at hand.

2) WRI recommends the Medium Investment BRT option based on our findings on cost-effectiveness and $CO_2$ emissions benefits.

3) WRI believes that the inputs used to forecast greenhouse gas emissions by the AA/DEIS need to be improved before a final decision is made. (For example, we recommend revisiting the choice of emissions factors, type of fleet, and occupancy).

## Introduction

**About WRI**
WRI is a nonpartisan environmental think tank based in Washington DC. Our staff of 160 works on a broad array of environment and sustainable development issues worldwide, providing peer-reviewed research and analysis and working with a wide range of partners to find practical solutions to some of our world's most pressing problems.

WRI has a goal to promote socially, financially, and environmentally sustainable transportation solutions based on well-informed and participative decision-making processes. With this in mind, we believe that a comprehensive impact assessment of proposed transport projects is critical to the decision-making process.

The World Resources Institute (WRI) appreciates the opportunity to comment on the Purple Line Alternatives Analysis / Draft Environmental Impact Statement (AA/DEIS). We commend MTA for striving to undertake such an assessment through the AA/DEIS, and for working to ensure an extensive and open public participation process. Our experience indicates that incorporating public input into decision making will likely lead to better outcomes for the project under consideration.

We are submitting these comments on the AA/DEIS for two primary reasons. First, as a local organization with many staff living near the proposed route, we have a direct stake in seeing the best possible alternative selected. Second, we have significant experience analyzing and implementing sustainable transit solutions around the world, and wish to bring our expertise to bear on this important local issue. While we have not joined any particular group or coalition either supporting or opposing the Purple Line project, we have consulted with a diverse group of stakeholders to gather information and insights on the project, and we have assessed key elements of the AA/DEIS with a commitment to objectivity and analytical rigor. In accordance with WRI policy, this document has been peer-reviewed prior to submission.

We have elected to focus on the following areas where we believe we can add the most value:

1) A general review of the merits of building robust, sustainable mass transit alternatives.
2) A sensitivity analysis of cost and ridership projections in the AA/DEIS.
3) An evaluation of the AA/DEIS's emissions projections for carbon dioxide, the primary greenhouse gas.

We expect that other stakeholders will comment on additional important concerns about the proposed system, such as whether to tunnel under downtown Silver Spring and Wayne Avenue or how best to preserve the Capital Crescent Trail. While we defer to these local communities on the best way to resolve these concerns, based on our discussions with stakeholders it appears that these issues have not yet been fully addressed. Thus we encourage MTA to continue working with the affected communities—even after selection of the locally preferred alternative—to find satisfactory solutions.

## Our Region's Sustainable Transportation Imperative

The Purple Line initiative offers the Washington DC Metropolitan Area the opportunity to take a national lead in providing 21st century solutions to the decades-old problems of traffic congestion and associated pollution. At a time when clean energy and fuels are a major and growing policy concern, both nationally and at the state level, we have an opportunity to improve outdated transport infrastructure, provide better transit options for the traveling public, and reduce our region's impact on global warming.

Major capital projects implemented in the near-term will shape the long-term future of transport in the region. WRI urges regional planners and other decision makers to consider current needs and concerns in the context of tomorrow's transportation challenges, especially regarding traffic congestion, fuel costs, and climate change.

Cities across the United States face similar challenges in updating transportation infrastructure, and those that develop cost-effective transport systems with an ability to accommodate present as well as future needs are the most likely to achieve long-term success. Mass transit systems and transit-oriented development are essential strategies for fostering such outcomes.

### Challenges and Trends

WRI wishes to emphasize the implications of the long-term regional transportation outlook on the Purple Line decision-making process. Decision makers must recognize these challenges and acknowledge related trends that will impact the region's future transportation needs, such as:

- increasing traffic congestion with a growing regional population;
- crowding on Metro and bus lines throughout the DC area; and
- volatile fuel prices due to projected scarcity, growing demand, and anticipated greenhouse gas regulations.

According to projections from the Metropolitan Washington Council of Governments, congestion and crowding in 2030 could be pervasive. Vehicle miles traveled (VMT) is expected to grow more than twice as fast as highway and road capacity, from 109 million miles in 2000 to 150 million miles in 2030. Capital Beltway traffic is projected to be at a continual "stop and go" pace by 2030, largely due to heavy westbound and suburb-to-suburb travel. Existing transit options will be strained to the limits, with heavy peak-hour crowding across the Metro system.[1]

It is also important to plan for the prospects of rising fossil fuel costs and increasingly stringent greenhouse gas (GHG) regulations. Increasing gas prices and a need to shift to low-carbon transport options are often discounted or ignored in transportation planning. Yet these factors significantly influence future transportation needs and must be factored into near-term planning.

[1] See Metropolitan Washington Council of Governments. 2006. "What if the Washington Region Grew Differently?" Results to date of the Transportation Planning Board's Regional Mobility and Accessibility Study: http://www.mwcog.org/uploads/committee-documents/vVpdWlk20060118160021.pdf

In light of such trends, the costs and benefits of MTA's various build alternatives need to be carefully weighed against the costs of a business-as-usual (i.e., No Build) approach to transportation.

The Transportation System Management (TSM) option does have some appealing attributes relative to No Build and is a low-cost alternative. On its own, however, TSM is a wholly inadequate solution for addressing long-term transportation needs in the east-west corridor. While it might provide some short-term benefits, these would be quickly overwhelmed by expected growth, and within a few years the region would likely be back to where it started: contemplating various BRT and LRT alternatives, only at potentially higher costs and in a more politically challenging environment.

**Key Questions for Transport Planners**

WRI urges decision makers to consider the outcomes of further postponement of a robust Purple Line. Concerns to consider include:

- Is current congestion and crowding at a point where a transit line is already overdue?
- Are marginal transportation fixes appropriate for addressing future population growth?
- Will traditional road building have fewer impacts on neighborhoods than mass transit?
- What transit alternatives will be available in the future if the Purple Line is delayed?

Other cities have taken a synergistic approach by complementing public transportation systems with policy instruments, aware that mass transit ridership can dramatically increase when targeted incentives are in place (see examples from Oregon in Appendix A). Market mechanisms such as congestion road pricing and dynamic parking pricing, alongside policy tools such as vehicle use restrictions and road space reallocation, have proven effective as Transportation Demand Management (TDM) strategies elsewhere.

WRI encourages decision makers to consider the positive cumulative benefits that a robust Purple Line would offer. Among other things, a well-designed system would shift more drivers to public transportation, reduce traffic congestion, and cut back on roadway maintenance costs. A Purple Line will not solve all of our regional traffic problems, nor is it intended to do so. However, as one small but important step in the right direction, this transit project and others like it can—if done right—add up to create a brighter transportation future for our region.

# WRI Sensitivity Analysis of Cost and Ridership Projections in the Purple Line AA/DEIS

## Summary

Estimated costs and ridership are key elements that define the differences between Purple Line alternatives, and their relative benefits and drawbacks. Understanding these variables should therefore be a crucial part of the decision-making process.

WRI examined the sensitivity of the cost and ridership projections provided by the AA/DEIS, using a Monte Carlo Simulation to model outputs under wide but probable variations for both of these critical projections.[2] Two scenarios were modeled: one in which the forecasts in the AA/DEIS were treated as accurate, and one in which the forecasts were treated as optimistic. Our analysis found that:

- The most robust alternative in terms of cost-effectiveness is Medium Investment BRT.
- There is very high risk that the High Investment BRT and all of the LRT alternatives will not meet the cost and demand projections in the AA/DEIS.

WRI strongly recommends that decision makers consider this information when selecting the locally preferred alternative for the Purple Line.

## Background

The summary of Key Evaluation Measures in the AA/DEIS presents point (single-value) forecasts of costs, demand, and user benefits (among other measures), based on standard professional practices. Unfortunately, standard professional practices do not account for the uncertainty associated with predicting costs and ridership.

There is enough evidence in the existing literature to indicate that cost and ridership forecasts are often optimistic at the planning stages. For example, B. Flyvbjerg et al. consolidated data for 44 urban rail projects, and found that average cost overrun was 45 percent and actual ridership was on average 51 percent lower than forecast.[3] The cases analyzed by Flyvbjerg et al. include the Washington Metro (which had a cost overrun of 85 percent) and the Baltimore Metro (which had a construction cost overrun of 60 percent and an actual ridership of 40 percent of the figure forecast in the opening year). Transit projects entail the double risk of higher costs and lower demand than expected, and it is better to incorporate such risks in the decision making process than to ignore them.

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[2] Monte Carlo Simulation is a probabilistic technique commonly used in financial analysis to model project outcomes to complex combinations of projects inputs. The Monte Carlo Simulation randomly and repeatedly generates values for uncertain variables. The results are analyzed to decide which variables are most likely to occur. It derives its name from Monte Carlo, the Monaco city near the South of France, which is known for its casinos. http://www.yourdictionary.com/monte-carlo-simulation

[3] Flyvbjerg B., Bruzelius N. and W. Rothengatter. "Megaprojects and Risk: An Anatomy of Ambition." Cambridge University Press, UK, 2003.

## Methodology

We used a method commonly employed in financial analysis to deal with uncertain futures and complex processes called Monte Carlo Simulation.[4] By using this process we sought to identify alternatives that are "robust" rather than "optimal" in that they fare well under a wide range of values of key variables, rather than performing best when a single future has been forecast.[5] We concentrated our analysis on three variables: cost, demand, and cost-effectiveness.[6] Results were compared based on cost per hour of user benefit, per guidance from the Federal Transit Administration (FTA). We conducted the Monte Carlo Simulation analysis for two scenarios:

1) The cost and ridership levels are represented by a probability distribution with the mean being the forecast values in the AA/DEIS.

2) The cost and ridership levels are represented by a probability distribution with the mean corrected for optimism.

We used these two scenarios because there is a need to incorporate uncertainty in the analysis, since we are dealing with future events that are uncertain by nature. Scenario 1 assumes the forecasts in the AA/DEIS are relatively accurate, while Scenario 2 assumes they are optimistic—consistent with the evidence of frequent optimism in planning for infrastructure projects as noted by Flyvbjerg et al. Assumptions for this analysis are presented in Appendix B.

## Results

The Monte Carlo Simulation simulation allows us to get direct probabilities for the variables of cost, ridership, and cost-effectiveness. Not surprisingly, the costs are always greater for the more sophisticated alternative. For example, Medium Investment LRT is greater than Medium Investment BRT, which in turn is greater than TSM. In addition, the demand is always greater for MI BRT than TSM, and 90 percent of the time greater for MI LRT than MI BRT. However, MI LRT is less cost-effective than MI BRT 88.5 percent of the time.

As Table 1 below indicates, the difference in average costs between alternatives is large (607 percent between MI BRT and TSM, and 110 percent between MI BRT and MI LRT). The difference in demand is large between MI BRT and TSM (206 percent), but is small between MI BRT and MI LRT (15 percent).[7] The difference in the FTA cost-effectiveness metric (cost per hour of user benefit) between MI BRT and MI LRT is moderate (52 percent).

[4] See footnote 2 for a definition of Monte Carlo Simulation.
[5] M. Wachs, Linking Forecasts to Action: Roles, Uses & Misuses of Forecasts in Transportation, Land Use, and Environmental Decision Making, Lake Arrowhead – UCLA, October 19-21, 2008.
[6] Cost-effectiveness is a metric that synthesizes the lifecycle costs (capital and operations) and the transport benefits of the project (total travel time reductions per user, multiplied by the number of users).
[7] The table shows results for Scenario 1 only, as the results for Scenario 2 were very similar in this case.

**Table 1. Simulation Results for TSM, Medium Investment BRT, and Medium Investment LRT**

| Variable | | TSM | MI BRT | MI LRT |
|---|---|---|---|---|
| **Cost** | Average | 82.0 | 579.8 | 1,220.2 |
| **(USD Millions)** | St. dev | 24.6 | 220.3 | 463.6 |
| **Ridership** | Average | 16,898 | 51,771 | 59,312 |
| **(Passengers per Day)** | St. dev | 8,411 | 14,218 | 15,113 |
| **Cost Effectiveness** | Average | n.a. | 15.9 | 24.2 |
| **(USD per Hour of User Benefit)** | St. dev | n.a. | 9.8 | 7.6 |

n.a. = not available

Next, as figures 1 and 2 below indicate, in Scenario 1 (the AA/DEIS forecasts are accurate):

- There is significant likelihood of the costs exceeding $1 billion for HI BRT (65 percent) and all LRT alternatives (83 to 98 percent); see Figure 1.
- The likelihood of costs exceeding $1.5 billion is 11 percent for MI LRT and 67 percent for HI LRT; see Figure 1.
- The likelihood of demand exceeding 32,000 passengers per day is high (75 percent for LI BRT through 98 percent for HI LRT); see Figure 2.
- The likelihood of exceeding 64,000 passengers per day is low for BRT options (3 to 36 percent) and moderate for LRT options (38 to 59 percent); see Figure 2.

**Figure 1. Cost Forecasts Probability Ranges – Scenario 1: AA/DEIS Forecasts are Accurate**

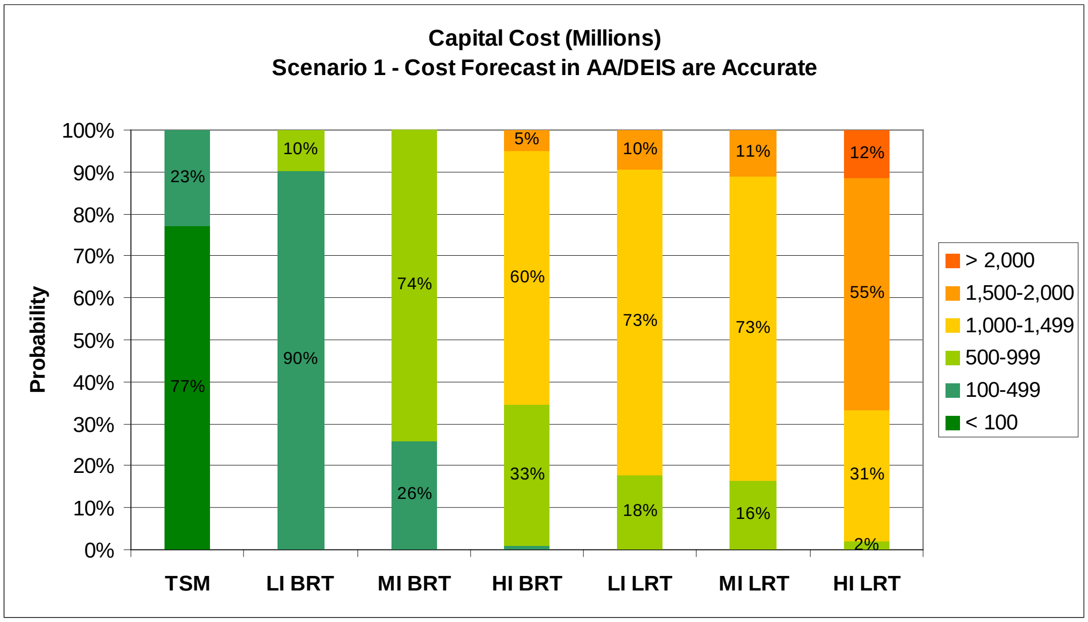
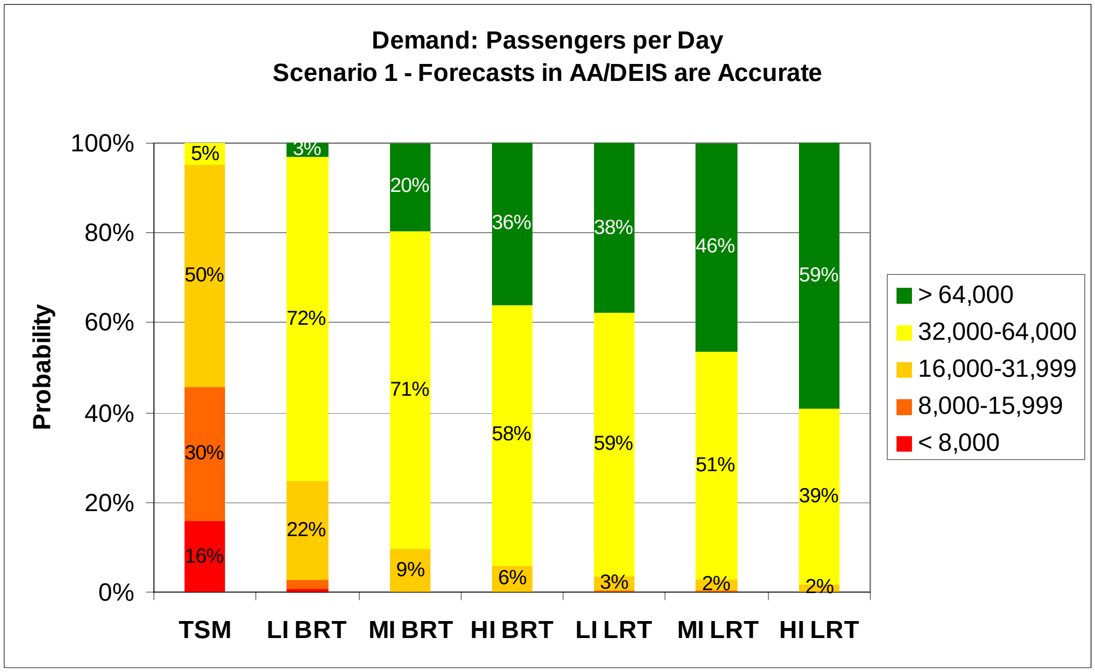


**Figure 2. Demand Forecasts Probability Ranges – Scenario 1: AA/DEIS Forecasts are Accurate**




Next, figures 3 and 4 below show that in Scenario 2 (the AA/DEIS forecasts are optimistic):

- The likelihood of costs exceeding $1 billion increases with respect to Scenario 1 for HI BRT (95 percent) and all LRT alternatives (99 to 100 percent); see Figure 3.
- For MI LRT the likelihood of costs exceeding $1.5 billion is 79 percent, while for HI LRT the likelihood of costs exceeding $2 billion is 80 percent; see Figure 3.
- The likelihood of demand exceeding 32,000 passengers per day is low for the LI BRT (23 percent) and moderate for the other alternatives (from 47 percent for MI BRT to 71 percent for HI BRT); see Figure 4.
- The likelihood of demand exceeding 64,000 passengers per day is negligible for LI and MI BRT and very low for HI BRT and all the LRT options (2 to 7 percent); see Figure 4.

**Figure 3. Costs Forecasts Probability Ranges – Scenario 2: AA/DEIS Forecasts are Optimistic**

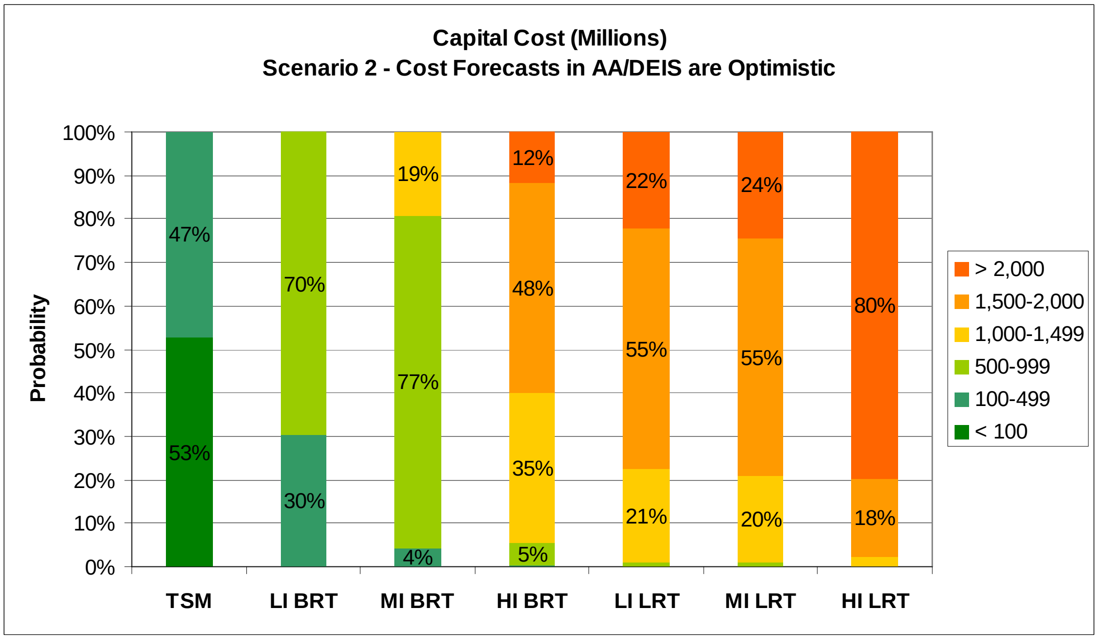
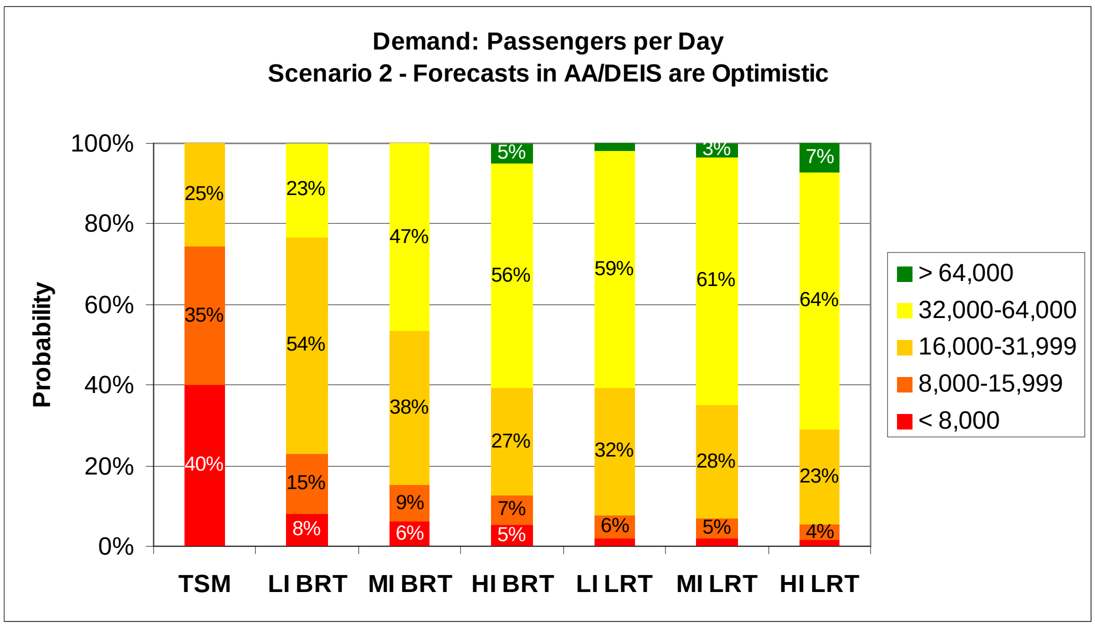



**Figure 4. Demand Forecasts Probability Ranges – Scenario 2: AA/DEIS Forecasts are Optimistic**




Finally, regarding cost-effectiveness (cost per hour of user benefit) our results indicate the following (see figures 5 and 6, below):

- The most robust alternative across the scenarios we modeled is Medium Investment BRT. Under Scenario 1 (accurate forecasts; see Figure 5), it has an 82 percent probability of being below $24 per hour of user benefit (FTA medium level) and a 56 percent probability of being below $15 per hour of user benefit (FTA medium-high level). Under

Scenario 2 (optimistic forecasts; see Figure 6), MI BRT has a 24 percent probability of being below $24 per hour of user benefit.

- The most robust LRT alternative is Medium Investment LRT. Under Scenario 1 (see Figure 5), it has a 58 percent probability of being below $24 per hour of user benefit and a 10 percent probability of being below $15 per hour of user benefit. Under Scenario 2 (see Figure 6), the probability of getting a medium FTA rating is only 0.6 percent.

**Figure 5. Probability of Meeting FTA Cost-Effectiveness Assuming Accurate AA/DEIS Forecast**

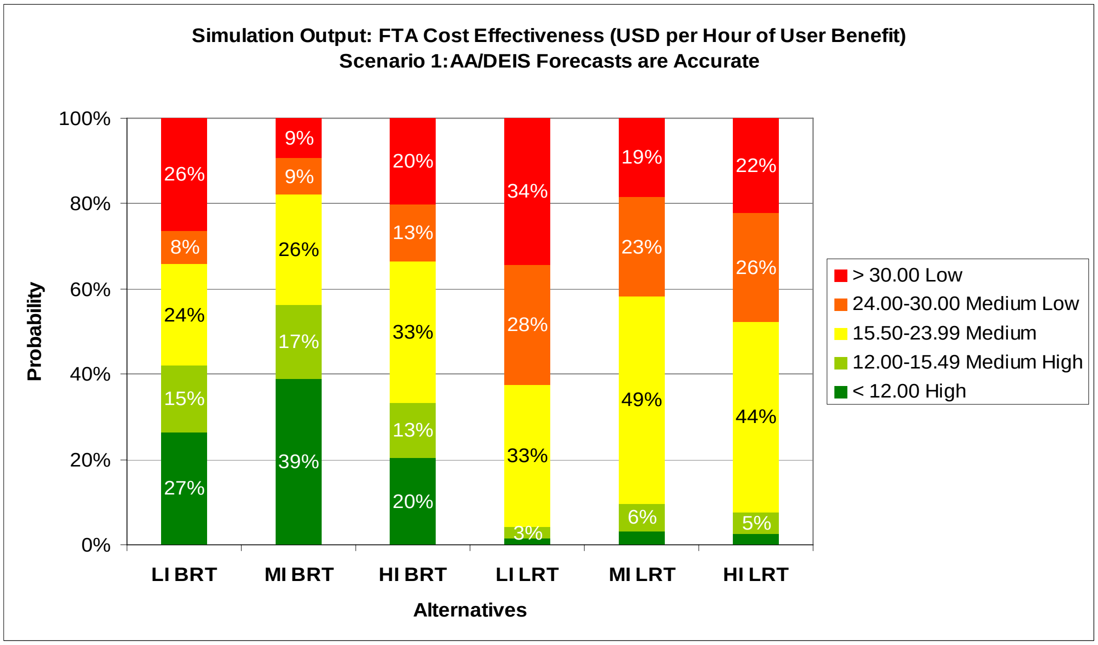
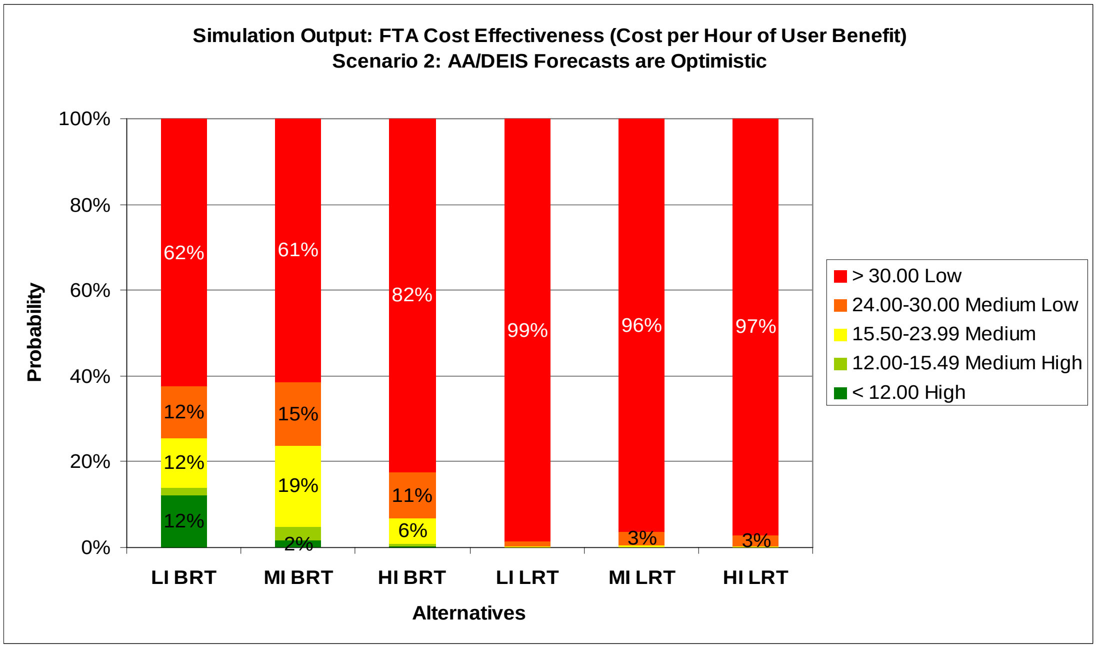



**Figure 6. Probability of Meeting FTA Cost-Effectiveness Standards Assuming Optimistic AA/DEIS Forecast**



**Sensitivity Analysis: Recommendations and Next Steps**

WRI recommends combining this sensitivity analysis with other inputs to the decision-making process. Regarding cost-effectiveness, our analysis confirms that the most robust alternative is Medium Investment BRT. High Investment BRT and all the LRT alternatives carry very high risks: it seems likely that the expected cost-effectiveness of each will not be realized. Such risks can lead to a lower probability of receiving state and federal funding and undesired delays in project implementation.

Through our participation in the Purple Line process, we recognize that BRT is not considered as attractive an alternative as LRT in terms of political viability. This may be the result of scarce or misleading information on the potential quality and performance of BRT.[8] To improve this situation, we suggest that decision makers and other stakeholders seek additional information on the quality of service and impacts associated with existing BRT projects in North America, such as the EmX Line in Eugene, Oregon (see Appendix A); the Los Angeles Orange Line; the Cleveland Healthline on Euclid Avenue; and the Select Bus Service System in New York City.

As design can be improved in the next phases of the project, selecting BRT would open the opportunity for operational designs that do not necessarily require passenger transfers among local and BRT buses. Buses operating on the local highway network might also be able to use the BRT facilities, thus saving time, as is the case with Ottawa's Transitway. Selecting LRT would preclude the use of such flexible operations.

[8] For additional information, see FTA's *Characteristics of BRT for Decision Makers*, available online at http://trb.org/news/blurb_detail.asp?id=4213

# WRI Greenhouse Gas Analysis of the Purple Line AA/DEIS


**Summary**

WRI's greenhouse gas (GHG) assessment of the various Purple Line options shows that, relative to the No Build scenario, the High Investment BRT alternative provides the greatest emission reductions, followed by Medium Investment BRT. Meanwhile, the TSM alternative results in the greatest emission increases, followed by the LRT options. WRI recommends combining this information with other considerations when selecting the preferred alternative for the Purple Line. In addition, we provide a list of recommendations on how to improve the current GHG assessment.


**Background**

WRI considers reducing greenhouse gas emissions from the transportation sector of utmost importance since this sector is a major and one of the fastest growing contributors to dangerous climate change. In the United States, transportation contributed approximately 31 percent of energy-related $CO_2$ emissions in 2005, second only to the power sector's contribution of approximately 47 percent (WRI, 2008).

Improving the efficiency of end-use activities (e.g., motorized road transportation and encouraging shifts to less fuel-intensive transportation modes) is paramount to reducing emissions from liquid fuels, consumption of natural resources, and dependence on volatile international energy markets. The impact on GHG emissions of mass transit solutions that draw their power from the grid, such as the proposed light rail transit options, depends on the fuel source used to produce the electricity.

For these reasons, WRI believes that transportation projects seeking government approval should include GHG emissions forecasts for all proposed alternatives, and that this criterion be included in the decision-making process. In addition, procedures should be put in place to monitor emission levels once the project has been implemented in order to verify if the forecasts were accurate. Finally, efforts should be made to promote more efficient and less polluting transportation modes and to significantly increase the share of renewable energy that powers the electricity grid.

**Methodology**

WRI reviewed the AA/DEIS greenhouse gas assessment provided in the Air Quality Technical Report, as well as the Traffic Demand and Energy Technical Reports. To complement these studies, we performed a number of calculations to better understand the methods used and the origin of the numbers presented.

With the aim of recommending how the GHG assessment could be strengthened, we provide the following feedback, covering:

1) Assumptions made and disclosed in the AA/DEIS.

2) Methodologies and key principles to observe when estimating emissions from transportation projects. (See Appendix C for a discussion on recommended methodologies for comparing transportation alternatives.)

A limitation of our analysis, and possibly the AA/DEIS itself, stems from the uncertainty associated with variables that affect many parameters in the study, such as:

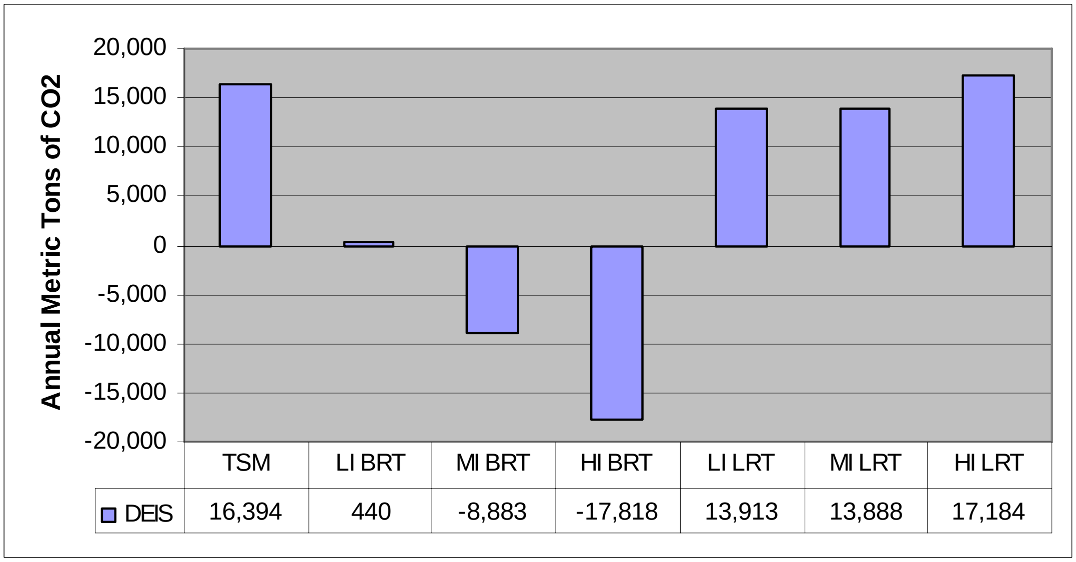
- the price of fuel;
- turnover in vehicle stock and effects on fleet-wide fuel economy from revised Corporate Average Fuel Economy (CAFE) standards;
- population and demographic projections; and
- the impact of likely GHG emissions control legislation on the price and emission levels of each alternative.

**Results**

In the AA/DEIS, the impact of Purple Line transportation alternatives on $CO_2$ emissions is presented in terms of daily metric tons of $CO_2$, with no estimate of uncertainty levels or provision of sensitivity analysis. The results are also presented in terms of percentage change from the No Build scenario and, as explained in the Traffic Analysis Technical Report, these estimates include vehicle miles traveled on roadways for the entire Washington DC Metropolitan Area. It could be expected that changes in emissions caused by a 16-mile local transit project would be small when compared to emissions from vehicles in the whole region.

To provide a better appreciation of the extent of emissions impact from the transportation alternatives, WRI therefore presents the results in terms of absolute annual metric tons, as illustrated in Figure 7. The values presented include emissions from mass transit and impact of modal shift (meaning the number of people who shift their mode of transportation from private vehicle to mass transit or vice versa). For comparison, the information could also be presented in terms of the equivalent number of passenger vehicles taken off the road. In the case of High Investment BRT, that number would be 3,260 based on average annual vehicle emissions of 5.46 metric tons $CO_2$-equivalent, according to the U.S. EPA (2008c).

**Figure 7. Comparison of Purple Line Impact on Annual $CO_2$ Emissions for 2030, Against the No Build Scenario**




(Source: Purple Line AA/DEIS, 2008)

As illustrated in Figure 7, only the Medium and High Investment BRT alternatives reduce $CO_2$ emissions, with 8,883 and 17,818 fewer metric tons per year, respectively, compared to the No Build scenario. All of the remaining alternatives increase annual emission levels compared to No Build. Energy consumption from roadways decreases with introduction of LRT, but the resulting emissions reduction is not sufficient to counterbalance the effect caused by the high electricity $CO_2$ emission factor. While we anticipate that this emission factor will decrease in the future due to increased use of renewable energy sources and likely GHG reduction legislation, these drivers have not been included in the AA/DEIS. Further consideration is given to the electricity emission factor in the following sections.

The difference of impacts on emissions levels, when presented in absolute terms, can be considered small when compared to regional, national, and global emission levels. However, the variance between transportation alternatives—approximately 35,000 metric tons per year and equivalent to to the annual emissions of over 6,400 passenger vehicles (US EPA 2008c) when comparing High Investment BRT with High Investment LRT—should not be dismissed. In fact, the only way to meet anticipated national GHG emissions targets needed to stabilize climate system will be in making numerous emissions reduction interventions, large and small, across the U.S. economy.

## Exploration of AA/DEIS Assumptions

In our analysis, we explore a selection of parameters used in the AA/DEIS estimation of $CO_2$ with the goal of providing additional information of value for decision making. The parameters selected were based on the assumptions available in the AA/DEIS:

- electricity emission factors;
- mass transit vehicle occupancy rates; and
- alternative fuel and bus vehicle technologies.

Some assumptions used in the AA/DEIS were not disclosed and therefore could not be evaluated.

**Electricity emission factors.** The choice of electricity emission factors used in the Purple Line analysis affects the net emissions anticipated from the LRT options because the LRT system would be powered by the electricity grid. Electricity emission factors vary significantly depending on the mix of energy feedstocks and their respective carbon intensity; for example, hydropower has a relatively low carbon intensity compared to coal.

While the AA/DEIS used a Maryland state-based emission factor in performing these calculations, WRI proposes using a sub-regional emission factor instead, such as those found in the U.S. EPA's Emissions & Generation Resource Integrated Database (eGRID), to more accurately capture the true emissions intensity of the power plant coverage area providing electricity to the Purple Line LRT (US EPA 2008b). This would be consistent with existing best practices such as those used by the California Climate Action Registry, the Climate Registry, and EPA's Climate Leaders, all of which build off the WRI/WBCSD Greenhouse Gas Protocol's *Corporate Accounting and Reporting Standard, 2nd Edition* (US EPA 2008a, US EPA 2008b, WRI/WBCSD 2005, Climate Registry 2008).[9] The United Nations Framework Convention on Climate Change (UNFCCC) also recommends using regional grid data for large countries where this information is available.

We used EPA's eGRID documentation and its Power Profiler website to identify the appropriate emission factor. Based on the ZIP codes for all Purple Line areas from Bethesda to New Carrolton, the project area falls entirely in the RFC East sub-region which encompasses portions of Maryland, Pennsylvania, Delaware, and New Jersey. This area's electricity generation and service is overseen by the Reliability*First* Corporation (RFC).

Several aspects of the grid emission factor merit further analysis, as this number bears great influence on the net GHG emissions caused by electricity-driven LRT options. This can in turn affect the favorability of LRT options in comparison to other alternatives. While the AA/DEIS's projections indicate that all three LRT alternatives would result in a net emissions increase compared to No Build, we believe this increase is likely smaller than forecast in Chapter 4 of the AA/DEIS (page 4-48). Quantifying Purple Line emissions using the regional emission factor would result in a 50-60 percent reduction in emissions for LRT options compared to the AA/DEIS forecasts, as shown in Figure 8.[10] WRI believes this emission reduction would still be conservative, as the eGRID-derived factor is a current figure and does not incorporate expected drops in carbon intensity for the power sector.

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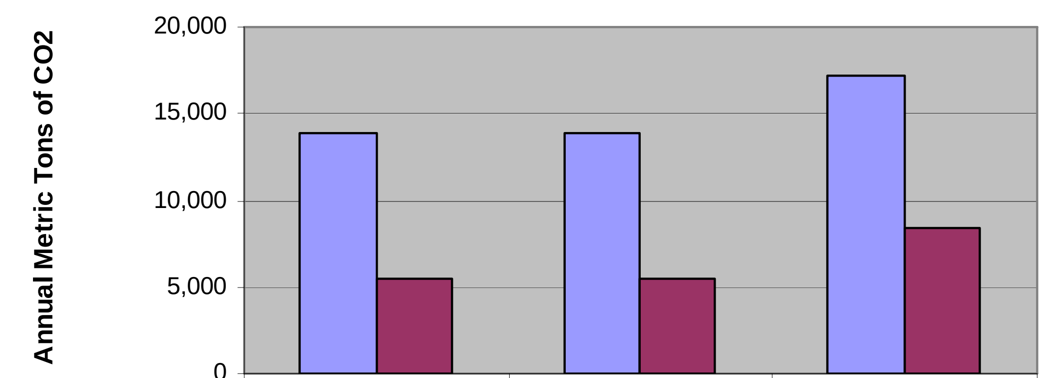
[9] By using the Maryland state emission factor, the AA/DEIS implicitly states that the LRT system will draw electricity from the central grid instead of from an off-grid captive power plant which would have a separate emission factor. We maintain this assumption since no indication otherwise is presented.

[10] The AA/DEIS uses a grid emission factor of 401.5 lbs. $CO_2$/million BTU, which can also be expressed as 1370 lbs. $CO_2$/MWh, since 1 kWh = 3412 BTU. As the Purple Line project falls under the RFC East region in EPA's eGRID, the appropriate regional emission factor would be 1090.5 lbs. $CO_2$/MWh, a 20.4 percent decrease. Note that even though the RFC East emission factor is 20.4 percent less than the emission factor used in the AA/DEIS, LRT emissions result in a 50-60 percent reduction from AA/DEIS forecasts when incorporating effects from the modal shift (i.e., reduced private vehicle emissions).

**Figure 8. 2030 Annual GHG Emissions with AA/DEIS and RFC East Electricity Emission Factors, Against the No Build Scenario**[11]




| | LI LRT | MI LRT | HI LRT |
|---|---|---|---|
| DEIS | 13,913 | 13,888 | 17,184 |
| RFC East | 5,439 | 5,508 | 8,344 |

(Source for RFC East emission factors: US EPA. Emissions & Generation Resource Integrated Database (eGRID), 2008.)

Several states in eGRID's RFC East sub-region have passed renewable portfolio standards (RPS) requiring that utilities generate a set percentage of electricity from renewable sources by a specified year. In Maryland, this figure is 20 percent of the state's total electricity production with a minimum of 2 percent derived from solar photovoltaics by 2022 (DSIRE 2008). Since we do not know which fuel sources this renewable electricity will displace, or the emission factors for the renewable sources, we cannot be sure about which emission factor to use for 2030. Regardless, the number should be lower than the AA/DEIS's stock value, barring construction of new high-carbon-intensity power generation that would cancel the reductions caused by the introduction of renewable energy sources, and should be reflected in future GHG forecasts.

**Mass transit vehicle occupancy rates.** The AA/DEIS uses national average values of 8.7 and 22.4 passengers/mile for BRT and LRT systems, respectively. WRI believes that the occupancy rate selected for BRT is an underestimate since the U.S. average for conventional buses includes a mix of buses running in rural and urban settings, not all in BRT-type conditions.

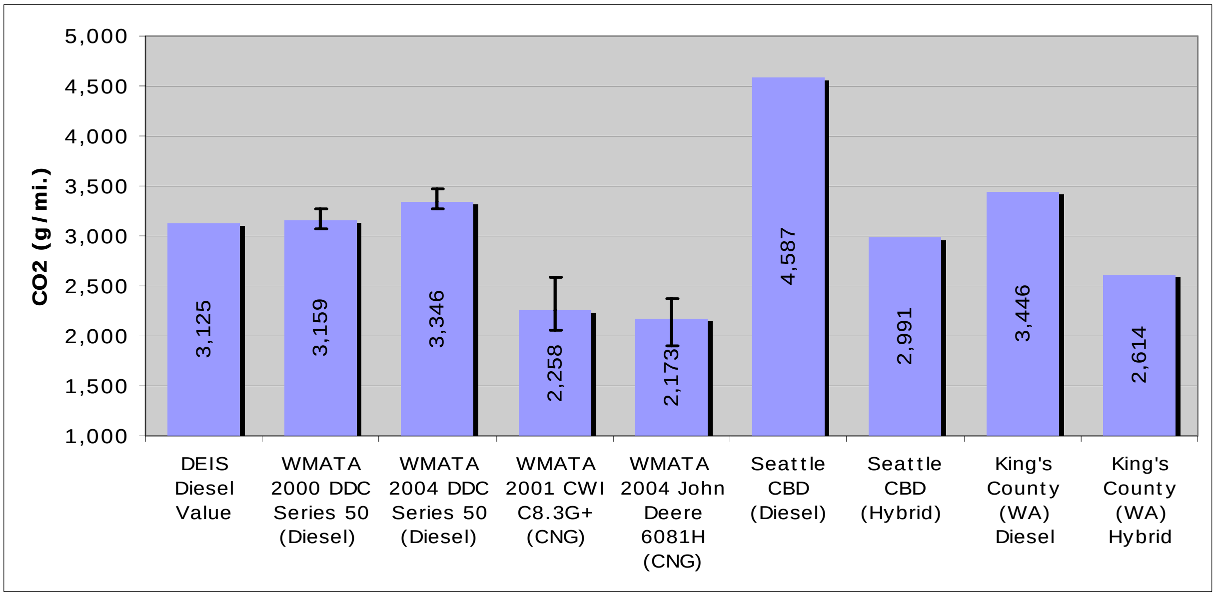
To be fair, there is a lack of reported data available on the average ridership of BRT systems in the United States. However, since systems like the Purple Line BRT options have similar operational specifications to LRT systems, the occupancy rate for the BRT should be much closer to the LRT estimate of 22.4 passengers/mile.

The higher passenger load has an impact on emissions since fewer miles are traveled to transport the same number of passengers, leading to reduced emission levels.

[11] The values presented in Figure 8 include the emissions from LRT and the modal shift incurred as a result of implementing LRT. If we were to isolate the emissions from LRT from the modal shift implications, the emissions change that results from using the sub-regional electricity emission factor would be lower, since modal shift causes a reduction in total LRT emissions.

**Vehicle propulsion factors.** The AA/DEIS uses single propulsion factor values for both BRT and LRT alternatives, which overlooks the range of fuel sources and technology types for either transit mode. Figure 9 depicts a range of propulsion values for potential BRT systems including diesel, compressed natural gas (CNG), and hybrid electric, based on studies developed for the Washington Metropolitan Area Transit Authority (WMATA) and the King County, Washington Metro Transit Authority.

**Figure 9. GHG Emission Intensities for Selected Bus Fuel and Vehicle Technology**

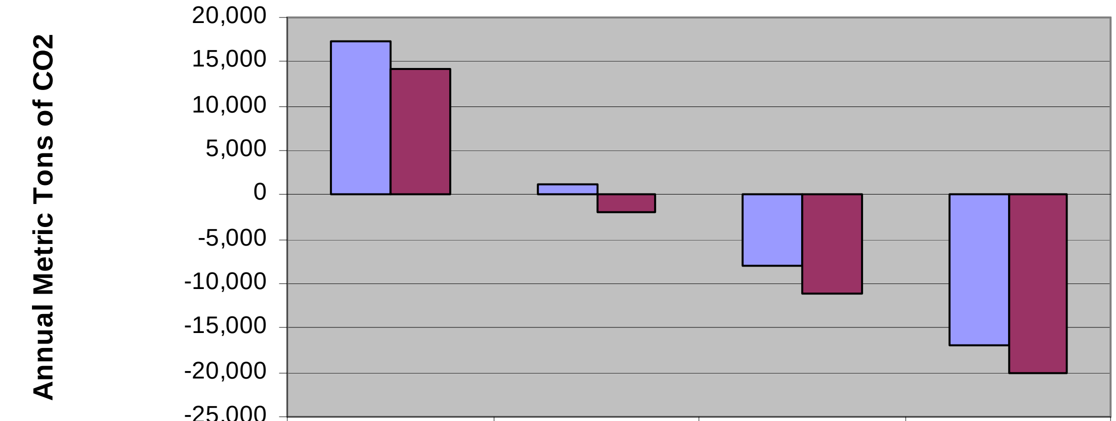



(Source: Melendez et al. 2005, Chandler and Walkowicz 2006.)

The error bars for WMATA vehicles represent the range of values obtained after multiple test runs conducted by the National Renewable Energy Laboratory (NREL) in Washington, DC (Melendez et al. 2005, Chandler and Walkowicz 2006). Figure 9 shows high variability in anticipated GHG emissions contingent upon engine and fuel type and driving cycles. The diesel buses operating in Seattle's Central Business District (CBD) emit over twice the emissions per mile traveled as some CNG bus classes operating in the Washington DC Metro Area, underscoring the significance that propulsion values play in determining net emissions. WRI therefore recommends that, when evaluating the impact of the Purple Line on emissions, bus propulsion values be explored.

For purposes of illustration, Figure 10 presents the impact of replacing diesel with CNG buses for the Purple Line TSM and BRT/LRT alternatives. In the AA/DEIS, all bus options are assumed to be diesel-based. As the figure shows, Medium Investment BRT using CNG technology would reduce $CO_2$ emissions by 38 percent compared to diesel technology.

**Figure 10. Comparison of Annual GHG Emissions in 2030 for Diesel and CNG Bus Technologies, Against the No Build Scenario**




| | TSM | LI BRT | MI BRT | HI BRT |
|---|---|---|---|---|
| Diesel WMATA | 17,243 | 1,290 | -8,051 | -16,977 |
| CNG WMATA | 14,094 | -1,859 | -11,139 | -20,095 |

(Source for emissions factors: Melendez, et al. 2005. Activity data from AA/DEIS.)

## GHG Assessment: Recommendations and Next Steps

- WRI recommends development of a more transparent and complete GHG assessment of the Purple Line alternatives. Key information needs to be centralized in one section of the AA/DEIS, key assumptions need to be disclosed, units need to be corrected throughout the technical reports, and values made consistent among the reports.

- WRI agrees with the AA/DEIS's findings that Medium and High Investment BRT systems will reduce GHG emissions while the TSM and LRT scenarios will increase emission levels. However, the AA/DEIS does not disclose all assumptions and may ignore several exogenous factors that influence the level of ridership and consequent emissions. To overcome this problem, emission levels could be presented in ranges or uncertainty levels disclosed.

- Conducting a sensitivity analysis would prove which variables are most influential in determining the final GHG emissions results. Thus, variables such as the BRT's fuel consumption or propulsion factor should be tested for each of the configurations potentially composing the Purple Line BRT fleet (e.g., CNG, diesel, hybrid). Our results show that depending on the propulsion value selected net emissions may vary by 20+ percent.

- WRI suggests using a sub-regional emission factor for electricity consumption instead of state-based emission factors, as explained earlier.

- We propose using similar vehicle occupancy rates for LRT and BRT since they would be designed to provide similar levels of transportation service. Occupancy rates can be expressed as an average or a range, the latter enabling a better appreciation of the variability that exists between systems.

- Any estimates of percentage change in emissions due to the Purple Line can be misleading as in Table 4.7-5, by making relative comparisons to the Washington DC Metro Area's aggregate emissions. Instead, these numbers should be judged in absolute terms, or at a minimum compared to total $CO_2$ emissions burdens for only the Purple Line region, and not the entire DC area.

- Future analyses should incorporate variable uncertainty into their forecasting models, since point estimates provide no insight into the range of possible values these quantities may assume. Where information is unavailable regarding standard deviations and probability distributions, a qualitative treatment and estimated value ranges should be provided and justified. By including substantiated minimum and maximum values (for quantities such as annual GHG emissions or total daily boardings) in policy analyses, policymakers are able to make informed decisions based on improved information that point estimates cannot provide.

## Appendix A. LRT and BRT Case Studies: Portland and Eugene, Oregon

In detailing the alternatives under consideration, the AA/DEIS rightly points to examples of other U.S. localities where comparable transit systems have been implemented. It is often instructive to study the experience of other cities, and we welcome this approach. To add to this discussion, we also offer two brief but instructive case studies of successful LRT and BRT systems in Oregon.

<u>Transit Project Experiences and Lessons from Oregon</u>
Oregon has a well-deserved reputation for progressive transportation and land-use planning. For 35 years the state has planned around established urban growth boundaries that encourage efficient land use and protect natural areas as well as air and water resources. Several Oregon cities are often cited as the gold standard in implementing sustainable transportation strategies through mixed-use, transit-oriented development. A brief look at two such examples can provide lessons for Maryland’s proposed Purple Line system.

### *Portland’s Metropolitan Area Express (MAX)*

<u>Key Statistics (all lines combined)</u>
Construction Costs: $1.65 billion
Length: 44 miles
Stations: 64
Daily Ridership: ~100,000 trips
Annual Ridership (FY07): 34 million trips

**Portland's MAX light rail system (photo by Andrew Collins)**

Portland installed the first of four segments of the MAX light rail system in 1986 with funds reallocated from capital originally marked for highway development. Subsequent segments were constructed in 1998, 2001, and 2004. Today the MAX ranks among the top five systems nationwide in terms of ridership and is an example of successful, proactive long-term transportation and urban planning.

Overall, ridership has grown some 200 percent between 1997 and 2006 (population increased 11 percent during this period). Investments in additions and extensions have been driven by the following:

- Billions of dollars in savings through avoided infrastructure costs including urban freeways, neighborhood disruptions, and increased air pollution
- Dedicated right-of-way within the existing road system, crossing local streets at grade in coordination with the roadway signal system
- Success in facilitating compact, mixed-use development around stations
- Riders' familiarity with the MAX system
- A defined transit role within a balanced transport system that includes roads, freeways, bike routes, sidewalks, and other modes of transport

A fundamental reason for transit success in Portland has been an effective long-term vision that guides near-term implementation strategies. The region has an overall planning horizon that reaches out to 2040. The city also has a Metro Regional Transportation Plan that sets 20-year development strategy for the transportation system—a long-term perspective providing critical direction for near-term transit system implementation plans. This integrated, long-term approach allows the region to prepare for future challenges and develop appropriate transportation options to meet demands.

*Eugene-Springfield Emerald Express (EmX)*

<u>Key Statistics (all lines combined)</u>
Construction Costs: $24 million
Length: 4 miles (+7.8 miles in 2010)
Stations: 10
Daily Ridership: 8,000 - 10,000 trips
Annual Ridership (FY07): 1.4 million trips


**Eugene's EmX BRT system (photo courtesy of Eugene Lane Transit District)**

In contrast to Portland's MAX system, the EmX in Eugene, Oregon is a smaller transit system based on a bus rapid transit (BRT) model. The EmX Green Line, which opened in 2007, provides a commuter connection between Eugene and Springfield—a metro area of approximately 330,000 residents expecting significant population growth over the next several decades.

The region weighed several transit alternatives as part of the planning process. Considering financial resources and the current population density of the areas, planners decided on a BRT system as the best option and noted it would not preclude light rail options for the corridor in the future. Planners also considered traditional bus service, but deemed this inappropriate due to projected congestion in the corridor that would delay bus travel and diminish public appeal.

Ridership has thus far exceeded projections due to high fuel costs and positive community reactions to the BRT's appearance and convenience. Elevated platforms, art, landscaping, and the sleek design of the hybrid buses have all contributed to general public popularity. Signal priorities and exclusive right-of-ways (60 percent of the corridor) enable accelerated service. The city is pursuing plans for additional EmX corridors in 2010 and 2015.

## Appendix B. Assumptions for Sensitivity Analysis

Table B1. Inputs to Monte Carlo Simulation

| | Forecast is Accurate | | Forecast is Optimistic | |
|---|---|---|---|---|
| | Capital Cost (USD) | Demand (passengers/day) | Capital Cost | Demand |
| TSM | 81,960,000 (s.d. 30%) | 16,900 (s.d. 52.4%) | +20% (s.d. 30%) | -39.5% (s.d. 52.4%) |
| LI BRT | 386,390,000 (s.d. 38%) | 40,000 (s.d. 52.4%) | +45% (s.d. 38%) | |
| MI BRT | 579,820,000 (s.d. 38%) | 51,800 (s.d. 52.4%) | | |
| HI BRT | 1,088,480,000 (s.d. 38%) | 58,900 (s.d. 52.4%) | | |
| LI LRT | 1,206,150,000 (s.d. 38%) | 59,300 (s.d. 52.4%) | | |
| MI LRT | 1,220,150,000 (s.d. 38%) | 62,600 (s.d. 52.4%) | | |
| HI LRT | 1,634,840,000 (s.d. 38%) | 68,100 (s.d. 52.4%) | | |

Note: Probability distributions are assumed normal with Mean and Standard Deviation according to the table. Simulation assumes that the probability distributions are not independent. Correlation is 50% between BRT and TSM, and 50% between LRT and BRT. Source of variations: B. Flyvbjerg, M.K. Skamris Holm, S.L. Buhl.

**Appendix C. Methodology for Comparing GHG Emissions of Transportation Alternatives**
(Based on Cordeiro M., Schipper L. et al, 2008)

In the United States there are currently no officially approved methodologies to evaluate the impact of transportation projects on GHG emissions. WRI encourages developing standard methodologies for estimating emissions from transportation projects, upgrading transportation models to provide activity forecasts with lower uncertainty levels, and integrating land use, transportation, and emissions models. We recognize that emission forecasts are not devoid of uncertainty and the methods available still need improvement to offer more complete assessments. WRI recommends that project developers describe the methodologies used and clearly present the assumptions made in the analysis, so that reviewers and policymakers can understand the limitations of the assessment and make informed decisions.

Methodologies tend to be project-specific due to the nature of local transport interventions. To estimate the impact of proposed transit projects on emissions, we first need to define the assessment boundary based on the area within which the project has a significant impact on emissions. It should not be forgotten that a transport intervention has primary effects (intended changes on the transportation system) and secondary effects (unintended changes caused by the project activity). The secondary effects can cause one-time impacts such as emissions from construction and decommissioning of project activities, and may happen upstream (e.g., where vehicles and fuels are produced) or downstream of the project (e.g., changes in traffic or travel outside the project boundary). The impacts on non-project vehicles and people can be difficult and expensive to calculate. Although one may decide to ignore these effects, experience in some cities indicates that their impacts on emissions can be significant and cause an increase or decrease in overall emissions.

For the benefit of completeness and transparency, the methods and assumptions used to define the GHG assessment boundary and the impacts upstream and downstream of the project should be explicitly disclosed. A rough estimate of upstream and downstream impacts can help assess their magnitude and significance before big investments in measurements are made. Where a project’s impact is considered negligible or within the margin of error of the overall emissions reductions estimate, this impact can be dismissed or a conservative assumption of its magnitude should be made.

In broad terms, the framework to estimate $CO_2$ emissions from transportation projects should include seven main steps: (1) land-use forecasting, (2) travel demand forecasting, (3) transportation systems operations analysis, (4) modal and vehicle activity analysis, (5) fuel and emission factors analysis, (6) fleet and vehicle characteristics analysis, and (7) emissions estimation. Land-use forecasting determines the changes in population and demography in the area of interest and spatially allocates people, households, and commercial activities. Travel demand forecasting estimates the level of travel, given the spatial outputs from a land-use model. Transportation systems operations analysis predicts the travel times, speeds, delays, and modal activity. The entire set of components forms a comprehensive procedure for analyzing the emission impacts of transport interventions. Additionally, there may be feedback between this systems operations analysis and previous components. For example, predicted travel times may influence land-use and travel demand, which in turn will affect systems operations. Given vehicle modal activity data, emissions can be predicted, possibly with information from technology/fleet and vehicle efficiency analysis.

There has been a call for integrating land-use and transportation models used in the metropolitan planning process, based on the recognition that land use influences transportation outcomes and that transportation investments influence land-use decisions. This integration has been accomplished at the aggregate level, but there is a need to better understand the behavioral linkages between daily household activity and travel patterns on the one hand, and long-term choices of housing and job location and vehicle ownership on the other, to provide a robust behavioral foundation for model development that incorporates these factors (University of Washington et al., 2001).

Two main elements form the interface between emissions and traffic simulations or models: the vehicle fleet distribution (vehicle type in terms of transport mode and emission characteristics) affected by the transport measure, and the emission and traffic simulation model (dis)aggregation levels. This (dis)aggregation refers to the size of spatial, temporal, and demographic categories used in the models, enabling them to more or less realistically represent transportation user behavior and emission rates.

Finally, it should be noted that many good models robustly interpret the real world and allow the effects of different scenarios to be compared, albeit under modeled and not real-world conditions. However, few models precisely capture reality within a known uncertainty band. The differences between reality and the modeling environment are due in part to uncertainties in the model's design, uncertainty in the base data and parameters (e.g., emission factors by class and age of vehicle, driver aggressiveness distribution, etc.), and uncertainties in the model's calibration (origin-destination surveys, on-road fuel consumption measurements, etc.). Uncertainty levels can be improved by using the same method and models to estimate emissions from project alternatives.

## Appendix D: Additional Observations Regarding AA/DEIS Reports

- *Energy Technical Report*
    - It is unclear why the creation of a Purple Line system would affect the number of heavy trucks, positively or negatively, as indicated in Table 2-1. A justification of this would be informative.
    - Though energy intensity values for cars and light trucks are taken from the DOE's Transportation Energy Data Book, it is not clear why a 1.2 passengers/vehicle value was used in the AA/DEIS when DOE indicates an average value of 1.57.

- No explanation is offered for the inconsistent values found in different sections of the AA/DEIS. For example, in Chapter 4 the VMT and daily direct energy demand numbers differ between Table 4.15-1 and Tables 4.7-4 and 4.7-5.

**Appendix E. Further Reading on GHG Emissions Assessments**

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