TECHNICAL MEMORANDUM

To: MDOT/MTA

From: Parsons Brinckerhoff

Date: May 21, 2008

Subject: Baltimore-Washington Investment Corridor: Evaluation of Transit Service Strategy Alternatives

This memorandum summarizes the work performed under Task 5 (Evaluation of Transit Alternatives) of the Baltimore-Washington Investment Corridor (BWIC) Travel Markets Study. After presenting several key observations, it identifies and evaluates alternatives to serve the markets with the most potential for high-capacity services. It also presents high-level cost estimates for several high-capacity transit alternatives. Finally, a series of potential opportunities for the Baltimore-Washington Investment Corridor are identified by the technical team.

Key Observations

Land Use, Population, and Employment

- Employment is projected to grow fastest in the BWIC districts of Muirkirk, Odenton, Laurel and Jessup; all of these districts are clustered in the middle of the study area (see Appendix A for population and employment exhibits).
- Population is projected to grow fastest in the DC core (1.6% a year) and in districts located at the fringes of the study area.
- Population within the DC central business district is projected to grow more than twice the rate of employment, resulting in an improved jobs-housing balance that may moderate the growth in longer-distance commute travel to DC. In contrast, employment is not expected to grow significantly in Baltimore, the study area's other major employment concentration.
- With the exception of Odenton (Ft. Meade), population density and employment density are greater in districts along the Camden Line than in those along the Penn Line; forecasted growth is anticipated to make this difference even greater.
- Based on trends in population and employment growth and existing transportation and land use plans, improved transit orientation is expected in the following eight districts:
    - Silver Spring-Bethesda
    - College Park
    - Greenbelt
    - Muirkirk
    - Odenton
    - Columbia
    - BWI Airport
    - West Baltimore County
- Future land use patterns, which have a large impact on the extent to which transit can be an attractive option to travelers, are a source of uncertainty in this analysis. If land use does not become more supportive of transit use over the next 25 years, it is unlikely that those districts will be able to attract the share of potential transit trips identified in this study. Many of the districts in the middle of the corridor are currently lower density and auto oriented, and the extent to which state and local land use and transportation investment policies foster transit-oriented development in these districts will drive the success of major transit investments in the corridor.

Transit Markets

- The demand for transit in the traditional radial commute markets to Washington and Baltimore is anticipated to remain stable or grow at a modest rate during the study period, largely as a result of the improved jobs-housing balance in the District of Columbia and slow employment growth forecasted in Baltimore City.
- The reverse commute markets and the market for shorter trips between districts in the middle of the corridor are expected to grow, primarily due to projected employment growth within the middle of the corridor. The strongest growth in person trips is anticipated in markets where the current transit volume is low and existing transit services are limited. Examples include AM peak period trips from Baltimore to Columbia, from DC to Muirkirk, from Columbia to Odenton. These markets will be challenging to serve by transit, but present opportunities to utilize available capacity of existing radial services better in the reverse direction and to make transit, including fixed-route bus, more competitive by providing services where availability is currently limited.
- The travel market for non-stop service from central DC to central Baltimore is currently small, and despite forecasted growth, is not anticipated to be large by 2030 if only commute trips and other routine non-work trip purposes are considered. This suggests downtown Baltimore to downtown DC express service between the two downtowns exclusively should not be the focus of a transit strategy in the corridor.

Market Screening

In a previous memorandum (covering Tasks 3 & 4), eighteen markets were identified by grouping district-to-district pairs into common origins and destinations. That memo described how both directions of each market were qualitatively characterized on three attributes: trip length, volume and anticipated growth. Trip lengths were assessed on three categories: “short,” “medium” and “long,” depending on the number of districts to be passed through in the market. Anticipated growth was characterized as “declining,” “stable” or “growing,” whereas a plus-or-minus 10% change in the estimated transit volumes was used to denote “stable” conditions. The transit volumes were estimated and then categorized into one of four groups, ranging from “very low” to “high.”

The four volume categories offer one indicator of a corridor’s ability to support “very low” through “high” capital cost transit services. The potential transit demand in a corridor represents, in relative terms at least, the number of people who would potentially benefit from improvements in transit. Thus, this indicator can be useful for screening out corridors that may not be suitable for a large capital investment in transit, and for those corridors that are suitable, identifying priorities for further planning and evaluation of investment alternatives. The volume categories do not correspond to the amount of benefits each rider would receive, nor do they reflect the cost of delivering improved service.

The table below describes the potential peak period volume that can be accommodated by various illustrative transit modes as a function of vehicle size, the number of vehicles per consist, and a desirable peak hour frequency. The assumed values do not reflect the theoretical capacity of a mode, which could be much higher and vary depending on the level of vehicle crowding. The cost of providing service would depend on specific right-of-way characteristics. With these caveats, the table offers estimates of volumes that could be accommodated at crowding levels and frequencies that are likely to be attractive to choice riders and take advantage of the relative investment in facilities required to support the service.

Directional Volume Accommodated by Illustrative Modes

Modes	Approximate Vehicle Capacity	Vehicles per Consist	*Desirable* Peak Hour Frequency	Corresponding 3-Hour Peak Period Volume	Relative Capital Cost
Heavy Rail	120[1]	6	8 / hour	11,520	Highest
Light Rail	150	2	8 / hour	4,800	High
Commuter Rail	120	6	3 / hour	2,880	Moderate[2]
Bus Rapid Transit	75[3]	1	12 / hour	1,800	Low to High
Commuter Bus	40	1	3 / hour	240	Low

These volumes are similar to rail transit thresholds developed by Pushkarev et al. in *Urban Rail in America: An Exploration of Criteria for Fixed-Guideway Transit*.[4] When expressed in similar units, the Pushkarev thresholds imply that 9,375 peak period riders in the peak direction are needed to justify a low-cost heavy rail investment, and 15,000 are needed to justify a medium-cost heavy rail investment. For light rail, the Pushkarev thresholds imply 2,500 and 4,500 peak period riders (in the peak direction) are needed for low-cost and medium-cost light rail investments, respectively. Although the Pushkarev thresholds as well as the ones presented in the table above have significant limitations and do not consider many important factors that typically would be evaluated in an alternatives analysis, they can be a useful high-level planning tool for evaluating whether the demand in a corridor is "in the ballpark" of warranting high capacity transit service and whether high-capacity transit is worthy of further study. The Pushkarev thresholds for heavy rail and light rail transit, as well as the steps and assumptions used to convert these thresholds to equivalent three-hour peak period volumes, are presented in Appendix B.

For the purposes of screening and characterizing the size of the transit markets, the following table was used:

Volume Label	Peak Period Trips	Transit Service Standard
Very Low	Less than 240	Insufficient volume to consider low capital cost service
Low	Between 240 and 1,800	Sufficient volume to support the consideration of low capital cost service alternatives
Medium	Between 1,800 and 4,800	Sufficient volume to support the consideration of moderate capital cost service alternatives
High	Above 4,800	Sufficient volume to support the consideration of high capital cost service alternatives

As mentioned previously, it should be emphasized that potential demand alone is insufficient to identifying an appropriate mode for a particular market. Additional considerations include the presence of appropriate right-of-way (e.g., an existing rail line or expressway), desired travel speeds, capital cost, community and environmental impacts, and other factors, all of which can be explored more comprehensively and precisely in detailed alternatives analysis studies.

Screening Markets for Higher Capacity Service Potential

A key question of the BWIC study is which markets are likely to support high-capacity transit services. Identification of these markets allows for consideration of how effective the existing high-capacity facilities are meeting the travel needs of the corridor and allows for cost-effective prioritization of planning and implementation resources toward those markets likely to need new or expanded service.

[1] Based on WMATA Metro Rail planning standards.
[2] Assumes right-of-way is already available for commuter rail investments.
[3] Assumes articulated buses.
[4] Pushkarev, B., J. Zupan, & R. Cumella, Urban Rail in America: An Exploration of Criteria for Fixed-Guideway Transit, 1982.

High capacity investment decisions, especially fixed-guideways, are driven by volumes in the peak direction. Thus, for this screening stage, the volume in the busiest direction is compared against the volume thresholds described above for each of the eighteen markets. The markets were screened and those with a "medium" or above estimated transit volumes in 2030 are:

- Within the Beltway, North Radial, To DC
- Within the Beltway, Northeast Radial, To DC
- Mid-Corridor, Along Camden, To DC
- Mid-Corridor, Along Penn, To DC
- North Radial, To Baltimore
- East Radial, To Baltimore
- Southeast Radial, To Baltimore
- West Radial, To Baltimore
- Columbia, From Baltimore
- Columbia, From Odenton
- Between the Beltways, Along Camden, Both Directions

Markets not identified in the list above do not appear to have sufficient potential transit volume in 2030 to support a dedicated high-capacity facility by themselves. These markets may be served individually by lower-cost, lower-capacity investments, and they may also be served by a high-capacity facility that already exists to serve primarily other markets. The following section examines the effects of combining markets along common corridor lines to assess whether the combined (aggregate) market volumes might be sufficient to justify a high-capacity transit investment along key corridors within the BWIC.

Aggregating High-Volume Markets to Corridors

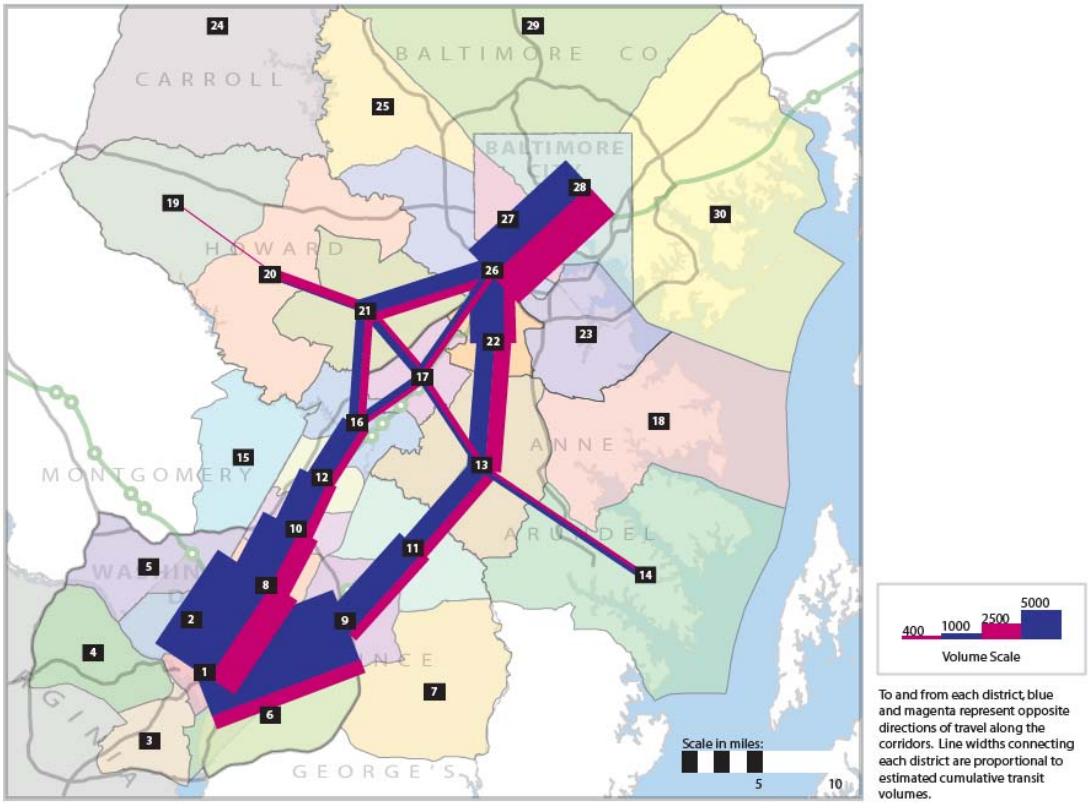
Many of the markets supportive of high-capacity investments identified above are generally aligned along common corridors. To understand the cumulative volume of travel along these corridors, to identify logical endpoint for high-capacity investments, and to align the markets more closely with projects proposed by stakeholders as alternatives to meet future transit demand in the corridor, the markets are aggregated according to the following table:

Relationship Between High-Volume Transit Markets and Key Corridors

Market	Corridor
Within the Beltway, North Radial, To DC	Corridor parallel to the Camden Line
Mid-Corridor, Along Camden, To DC	
Between the Beltways, Along Camden, Both Directions	
Within the Beltway, Northeast Radial, To DC	Corridor parallel to the Penn Line
Mid-Corridor, Along Penn, To DC	
Columbia, From Baltimore	Corridor between Columbia and Baltimore
Columbia, From Odenton	Corridor perpendicular to the main study area axis

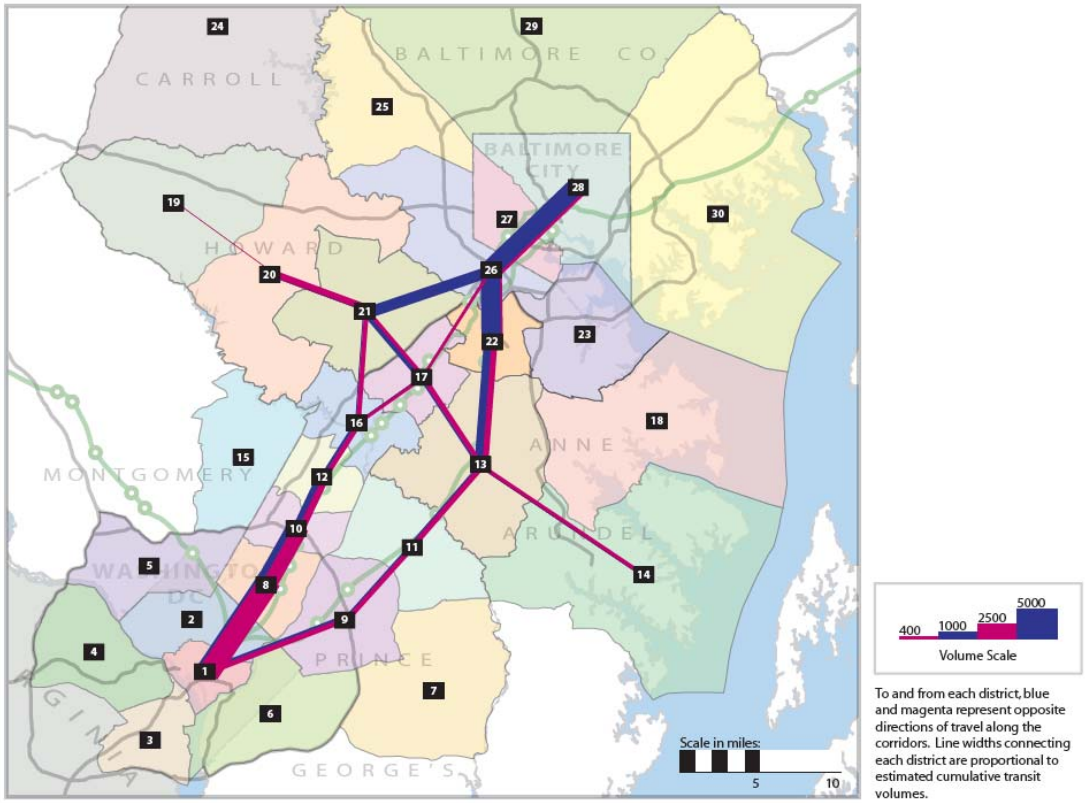
Detailed quantitative results of this aggregation are presented in the Tasks 3 & 4 memorandum. For easy reference, the cumulative volume aggregations for year 2030, as well as the growth in volumes between 2005 and 2030, are depicted in the maps below.

2030 Corridor Volumes (AM Peak Period)



To and from each district, blue and magenta represent opposite directions of travel along the corridors. Line widths connecting each district are proportional to estimated cumulative transit volumes.

Change in Volumes from 2005 to 2030 (AM Peak Period)



To and from each district, blue and magenta represent opposite directions of travel along the corridors. Line widths connecting each district are proportional to estimated cumulative transit volumes.

Corridor Findings

Corridor Parallel to the Camden Line

Demand in the corridor beyond Greenbelt is anticipated to grow, especially in the reverse direction, although inbound demand (toward DC) will continue to dominate the type of high-capacity facility required. By 2030, the estimated inbound transit volume leaving Laurel (district 16) is anticipated to be nearly 3,500 trips during the (three-hour) AM peak period, which drops off to less than 1,700 as one moves north to Columbia (district 21) or Jessup (district 17). This suggests the appropriate terminus of additional high-capacity service and/or major investment in the DC-focused part of the corridor may be in the vicinity of Laurel. Considerably less demand exists between Laurel and Baltimore along this corridor. Muirkirk (district 12) may be an appropriate interim stop that would offer improved auto access to WMATA park-and-ride facilities and could alleviate the need for some WMATA park-and-ride users to travel on the congested Washington Beltway (I-495) en route to the current Greenbelt Station terminus. An extension of the WMATA Green Line beyond the Washington Beltway with additional park-and-ride facilities at the new station(s) should have a small albeit positive impact on I-495 and I-95 highway congestion.

Alternatives to address this market appear to warrant additional analysis to understand the tradeoff between enhanced MARC service on the Camden Line and an extension of the WMATA Green Line. Moreover, growth in shorter trips between districts along this corridor suggests a need to improve fixed-route bus services to major employment and retail centers. An increase in transit frequency, reliability, travel speed, and span of service would help this market attract more regular commuters as well as other travelers.

High-capacity alternatives include:

- Extension of the WMATA Green Line (potentially as far as Laurel)
- Improved MARC Camden Line Service

Corridor Parallel to the Penn Line

Current demand for inbound service to DC may be underserved as evidenced by currently overfilled park-and-ride lots and trains with standing passengers on the MARC Penn Line. With an estimated current market size potential of more than 4,900 trips leaving the Bowie district (toward DC) during the AM peak period, this analysis confirms strong demand for increased MARC service on the Penn Line. By 2030, transit demand in the middle of the corridor is expected to be greater along this line than along the Camden line, largely as a result of the demand associated with the Odenton and BWI activity centers. The BWIC analysis also suggests that the market for transit trips ending in DC will grow at a modest rate, as a strong residential growth forecast for DC results in an improved jobs-housing balance and a corresponding slowing in long-distance transit demand.

Notwithstanding the trend in the traditional commute market, infrastructure and service improvements should be considered to accommodate strong growth anticipated in the reverse commute market. This will be particularly important if counties and local municipalities are successful at clustering forecast employment near MARC stations. One example of a market with large reverse commute growth potential is the BWI district (including both BWI airport and the surrounding area), which is estimated to have a potential 2030 AM peak period transit demand of 2,700 from the districts in the study area located north of BWI. Of those travelers, approximately 1,000 are expected to be coming from the City of Baltimore.

Like most airports, BWI has unique trip patterns with a greater percentage of airport worker and air passenger trips to the airport occurring outside the traditional commuting periods; approximately 6% occur during the early morning (4:30-6:30), 31% occur during the three-hour AM peak, 32% occur during the six-hour mid-day (off-peak) window, 14% occur during the three-hour PM peak, and 17% occur during other times. A considerable portion of trips also occur on weekends. Improvements to the

MARC Penn Line span of service, reliability, off-peak frequency, and weekend service are likely to increase the attractiveness of this option to travelers, particularly air passengers. Similar improvements to the MTA LRT service could also attract air passengers, but they would have a greater impact on airport workers because of the cost of travel (MARC being more expensive than LRT) and where airport workers live (approximately 31% of airport workers live in Baltimore City, which has good connections to the LRT).

High-capacity alternatives include:

- Improved MARC Penn Line Service
- Improved MTA LRT Service

Corridor between Columbia and Baltimore

Although the 2030 transit market between Columbia and DC (1,200 AM peak period trips) does not appear to be large enough to support high-capacity service, the reverse commute market from Baltimore to Columbia is more promising. This market is anticipated to more than double by 2030 and, with a potential 2,400 transit trips during the AM peak period, it may be able to support a moderate-capacity investment. This investment will be especially compelling if Columbia can improve its transit orientation as called for in its master plan.

Moderate-capacity alternatives include:

- Bus Rapid Transit

Corridor Perpendicular to the Main Study Area Axis

Significant job growth and improved transit orientation in the portion of the corridor between the Washington and Baltimore beltways suggests the need for a transit strategy to address suburb-to-suburb circulation where there is little existing transit service. Current market potential is low but anticipated to grow particularly between Columbia and Odenton. Potential corridor transit volumes approach 1,800 trips in the peak period by 2030. This suggests opportunities for right-of-way preservation should be explored for higher capacity services to keep transit competitive in an environment that may become increasingly congested. Interim express and commuter bus options may also be explored until demand justifies additional investment.

High-capacity alternatives include:

- Bus Rapid Transit (primarily between Columbia and Odenton)

Findings in Other Markets

East Radial, To Baltimore

In the development of a comprehensive rail plan for the Baltimore region, the MTA considered development of an east/west Light Rail line to serve corridor between downtown Baltimore and points east (i.e., east Baltimore County). The BWIC analysis supports the prior findings that this corridor could be a promising transit market, one that deserves continued study of high-capacity transit alternatives. Potential AM peak period transit demand in this corridor is high, nearly 6,000 trips, and it is anticipated to remain high through 2030.

High-capacity alternatives include:

- Bus Rapid Transit
- Extension of MTA LRT Service east of Baltimore
- Improved MARC Penn Line Service east of Baltimore Penn Station

Southeast Radial, To Baltimore
Potential transit volumes in this market (travel to Baltimore City from Annapolis, East Anne Arundel County and Glen Burnie districts) during the AM peak period are moderate, approximately 2,800 trips, and are projected to decline modestly through 2030. This decline can be attributed to slow projected employment growth in central Baltimore and diversion of trips in this market toward new employment opportunities in districts between the Washington and Baltimore Beltways such as Odenton, Columbia, and BWI. The declining demand suggests this market should remain a lower priority for additional study of high-capacity services.

Other Project Alternatives Proposed by Study Stakeholders

Extension of Metrorail Service to BWI or Odenton
The transit market to the BWI district from points south (e.g., DC) is expected to remain relatively modest despite projected growth in air traffic and regional population. Although approximately 84,000 air passengers are forecasted to travel to or from the airport per day in 2030,[5] almost doubling the 43,000 that do this in 2005, only 21% of BWI air passengers currently travel to/from places south of the Patuxent River within the study area. Of these expected 17,600 air passengers for the year 2030, approximately 1,300 are expected to travel to/from the airport between 4:30 and 6:30am, 2,700 are expected to travel during the three-hour AM peak period, 6,300 are expected to travel during the six-hour mid-day period, and the remaining 7,200 are expected to travel during other times of day. The overall travel demand does not appear to support consideration of a new high-capacity transit facility (given the current Amtrak and MARC service options), but improvements to the relatively low cost Penn Line MARC service (frequency, reliability, span of service, and weekend service), particularly improvements to service outside the peak periods, might convince more of these travelers to choose transit. It might also encourage some air travelers to chose BWI instead of another regional airport.

Similarly, although Odenton is expected to add more than 25,000 jobs due to BRAC, few (less than 500) of these potential transit trips to Odenton during the AM peak period are expected to come from destinations along the Camden Line. Given the high incremental cost of a Metro Rail extension to Odenton, MARC and local or shuttle bus improvements appear to be a much more cost-effective solution for serving this activity center.

The Baltimore-Washington Maglev Demonstration Project
The data used in this study included outputs from regional travel demand models and the census transportation planning package (CTPP). These datasets help describe travel demand for "regular commuter" trips and routine travel for other purposes. The market for cross corridor service serving the two downtowns exclusively for these purposes is very modest and should not be the focus of a transit strategy in the Baltimore-Washington Investment Corridor to meet the needs of commuters. Demand is estimated at approximately 1,700 peak period transit trips between the two downtowns. A very high-speed facility like the maglev project may serve an entirely different market comprised of business and excursion trips not well described by this analysis. Lower cost alternatives should be considered to serve regular commuters in this market, particularly during off-peak and weekend periods when services are modest or unavailable. Additional development of new high-capacity alternatives for this market does not appear to warrant additional analysis in this study.

Additional Considerations

[5] According to the 2006 BWI Long-Range Needs Assessment, the number of connecting passengers is estimated to be approximately equal to 20% of the total passengers through the airport, through 2030.

When deciding which, if any, investments to make within a corridor, many factors must be considered. While the factors below (as well as other factors) need to be explored in greater detail prior to making a major investment decision, this section discusses capital costs, travel times, potential highway impacts, and opportunities for lower capacity transit service to help inform the discussion of recommended next steps.

Capital Costs

Conceptual capital cost estimates are presented below for several high-capacity transit alternatives within the corridor (see Appendix C for additional detail on the cost estimates, the methodology used to produce them, and a map of the alternatives). While the following figures offer more precision than the qualitative estimates used in the market screening, they are still based on high-level planning methods, primarily based on typical costs and experiences from elsewhere. More detailed analyses, such as those performed in an alternatives analysis or feasibility study, would produce more precise estimates. And because all of the cost estimates are presented in year 2007 dollars, actual costs would be much higher once a construction schedule was developed, allowing the impacts of future inflation to be incorporated.

Green Line Extension

Below are conceptual cost estimates for a WMATA Green Line extension:

Conceptual Capital Costs for Green Line Extension

Metro extension to:	Length from Greenbelt	Capital Cost
Muirkirk	4.4	$660 mil
Laurel	7.6	$1,300 mil
Columbia	18.4	$2,475 mil
BWI Airport	23.0	$2,700 mil
Baltimore	31.3	$4,000 mil

Costs are not incremental – all costs in year 2007 dollars

MARC Improvements

Cost estimates have been prepared for a series of Penn Line and Camden Line investments identified in the 2007 MARC Growth & Investment Plan. Those improvements proposed by the plan for completion by 2010 within the BWIC are estimated to have a capital cost of approximately $135 million (in 2007 $), with $80 million of those costs associated with Penn Line improvements. The 2010 Penn Line improvements would lengthen trains; add peak, evening, and weekend MARC service; implement the first phase of park-and-ride expansion south of Baltimore; and lengthen station platforms. The 2010 Camden Line improvements would lengthen trains, add a mid-day train, provide minimal parking increases, and make some minor cosmetic improvements.

If the entire MARC Growth & Investment plan were implemented within the Baltimore-Washington Investment Corridor, total capital costs within the BWIC for improvements through year 2035 are estimated to be $1.82 billion (in 2007 $) for Penn Line improvements and approximately $400 million (in 2007 $) for Camden line improvements. The specific improvements associated with these cost estimates (for each five-year period) are listed in Appendix C.

Bus Rapid Transit linking Columbia, Odenton, and Greenbelt

A preliminary cost estimate was prepared for new bus rapid transit (BRT) services between the Columbia, Odenton, and Greenbelt activity centers. The specific BRT routes included in the cost estimate are:

1. Columbia to Odenton via Ft. Meade, and return.

2. Columbia to Greenbelt Metro station (or most northern Green Line station), and return.
3. Odenton/Ft. Meade to Greenbelt Metro station, and return.

To implement all three BRT routes, the estimated capital cost is $295 - $440 million (in 2007 $), but could be more depending on the amount of roadway reconstruction and ROW.

For the service between Columbia and Ft. Meade/Odenton (via MD 32), the capital cost is estimated at $120 - 185 million (in 2007 $), depending on extent of new construction on MD 32. The capital cost for the other segment (Savage to Greenbelt via US 1, connecting to MD 32) is estimated at $175 - 255 million (in 2007 $), depending on extent of new construction along US 1. All costs can be reduced by using existing roadways for some or most of each alignment at the expense of travel time, reliability, and ridership.

Travel Times of Alternatives

The mode used to serve a transit market will have a large impact on the number of riders that choose transit as well as the benefits that the users receive. For example, a transit trip from Muirkirk to the Gallery Place Metro station (in downtown DC) would take 32 minutes if it were served with a WMATA Green Line extension versus approximately 43 minutes if the trip used the Camden MARC Line. The faster travel time and avoidance of a transfer with the Green Line extension would not only make transit more attractive, but it would also save the user time that can be used for other beneficial activities.

While an alternatives analysis could perform a comprehensive analysis of the tradeoffs and develop an estimate of the benefits users would receive from high-capacity transit improvements, a comparison of travel times is presented in Appendix D to help inform the discussion.

Potential Highway Impacts

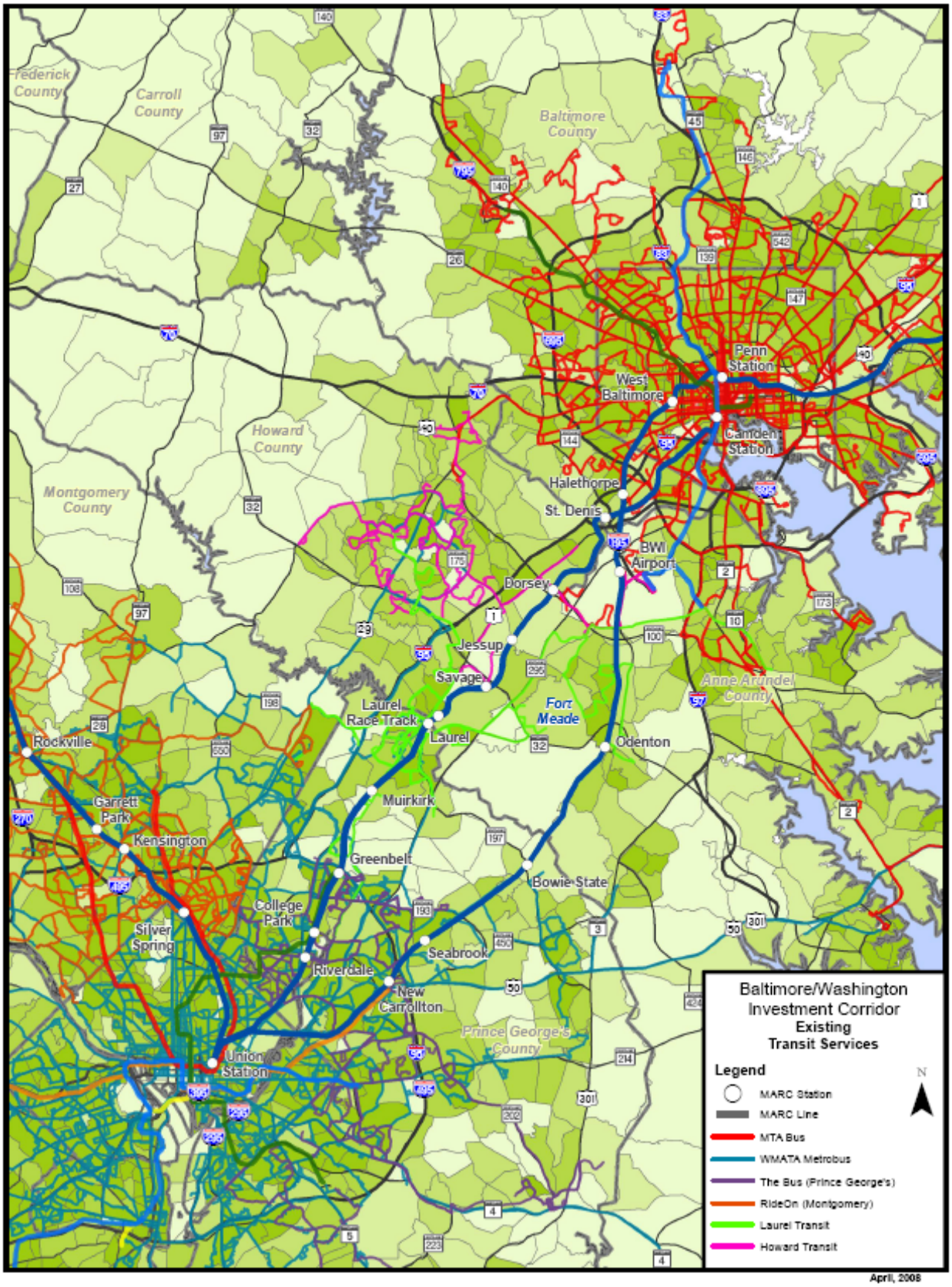
Potential improvements in the performance of the highway system will be proportional to the volume in the corridor and the trip length served because longer trips occupy more of the highway network than shorter trips. Opportunities for transit alternatives to alleviate key bottlenecks include extension of the Green Line beyond Greenbelt, which would eliminate the requirement that trips accessing the Greenbelt park-and-ride lot use the Washington Beltway.

Where highway expansion is considered in the corridor, opportunities to include transit-friendly amenities such as sidewalks, shelters, queue jumpers and dedicated bus lanes should be encouraged. This will keep surface transit competitive in the face of mounting congestion.

Opportunities for Lower Capacity Service

Existing fixed route transit services are show in the map below with the underlying analysis zones shaded to reflect relative population densities projected for 2030:

Existing Study Area Transit Services



Transit services are relatively sparse in districts between the Washington and Baltimore. Trips between these districts are relatively short and projected transit volumes are anticipated to grow through 2030. This suggests an opportunity to provide additional services to major employment and retail concentrations in addition to improving span and frequency on existing routes as ridership increases. Services that meet MARC trains at stations and connect to employment concentrations will be particularly important as the reverse commute market from both Washington and Baltimore grows. Serving the emerging market perpendicular to the main study area axis will require cooperation among multiple municipalities and/or counties.

Potential Opportunities

The technical team for the Baltimore-Washington Investment Corridor study suggests opportunities exist for policy, operational changes and capital investments to improve transit service in the corridor to meet current and projected future transit demand, such as:

Policies

Transit-Oriented Development

Significant population and employment growth is projected for the portion of the study area between the Baltimore and Washington Beltways. The competitiveness of transit for travel in this corridor will be driven by the degree to which this growth can be oriented toward existing transit services. Policies to encourage clustered development around existing MARC stations should be advocated. Local jurisdictions will play a central role in developing land use policies to encourage transit-oriented development, but specific actions at the state level include:

- Provide technical and financial assistance to local jurisdictions for station-area planning.
- Identify opportunities for highway and streetscape projects to provide supporting infrastructure for development.

Transit-Friendly Design

State transportation investments in the corridor should include transit-friendly design elements such as sidewalks along arterials and amenities at transit stops. To the extent possible, local jurisdictions should encourage site plans that provide convenient pedestrian access from transit stops to building entrances.

Clarification of Institutional Roles

Demand for new and expanded transit services within the corridor is increasing; however, it is unclear which entity would fund and deliver some of those services. The respective roles of the State and local governments should be clarified, perhaps using tools such as the transit service framework presented in the BWIC Task 3 & 4 Memorandum (dates April 29, 2008). An agreement or policy is needed to clarify that some service classifications (presumably higher or more regional in nature) are the responsibility of the State while other (more local) services are the responsibility of local governments or private entities.

Operational Changes

Commuter Bus Services

Existing commuter bus services (sponsored by the MTA) in the corridor are oriented toward the traditional radial commute to the centers of Washington and Baltimore. While this will continue to be a strong market for transit, this study suggests new markets will develop in reverse commute and suburb-to-suburb travel. Specific opportunities are identified to:

- Begin route-level service planning for fixed-route service in the east-west corridor market between Columbia and Odenton/Ft Meade.
- Monitor the existing commuter bus service between Columbia and Baltimore and Columbia and DC and increase service frequencies when necessary. Expand trips serving commuters traveling from central Washington and Baltimore to major employment concentrations that are not served by MARC lines.

Feeder Bus Services
Outside of the Washington and Baltimore central business districts, much of the employment in the corridor is not within a comfortable walking distance of MARC stations. Even with aggressive efforts to encourage transit-oriented development, it is likely that future commuters will need bus connections from MARC stations to their job sites. To adequately meet the growing demand in the reverse commute market, feeder bus services needs to be expanded. Potential initiatives could include:

- Initiate a discussion with local jurisdictions to identify a service framework to delineate which services that should be provided by the State, and which by the local jurisdictions.
- Include adequate space for feeder bus services near train platforms and explore opportunities for priority treatment for these services in potentially congested station environments.
- To make this service as attractive as possible, schedule feeder services to meet train arrival and departure times. For example, at the Odenton MARC station a timed transfer to shuttles destined for Ft. Meade makes transit a viable option for commuters along the Penn Line.
- Where demand is insufficient to support a bus connection from stations to an employment site, explore partnerships that offer employer-sponsored shuttles to make this connection.

Local Circulation Bus Services
Growth in demand for local transit travel will accompany population and employment growth forecasted between the Washington and Baltimore Beltways. Expanded local fixed-route bus service will be needed to meet the demand. Opportunities for expanding the service area, improving the span and frequency of Howard Transit and Laurel Connect-a-Ride could be pursued.

MTA Blue Line Light Rail Service
Detailed analysis of travel to BWI Airport suggests significant concentrations of worker and air traveler trips begin in Baltimore and could be served by the MTA light rail system. Travel to the airport does not follow the typical commuter pattern, and it would be a more attractive option for travel to/from the airport if earlier and later service were provided, seven days a week. MTA could consider a longer span of service to better match the travel times of airport employees and travelers.

Capital Investments

MARC Investment Plan
Revisit the MARC investment plan in light of more moderated growth forecasted for the traditional commute market to downtown Washington, DC, and significant growth in the reverse commute market. Potential opportunities for investment could be:

- Improvements necessary to meet current demand shortfalls on the Penn Line.
- Expanded off-peak and weekend service on the Penn Line to better meet the needs of travelers and workers traveling to/from BWI. Improved off-peak frequencies will also make reverse commuting more attractive.
- Phased implementation of service improvements and investments on the Camden Line, to develop higher quality transit service in the densest corridor and where much of the job growth and development is anticipated to be concentrated.

WMATA Green Line Extension

The corridor paralleling the MARC Camden Line north of the Washington Beltway was identified as having high volumes of potential transit trips. It is expected to grow modestly in the inbound direction and grow more significantly in the outbound, reverse commute direction. This finding, in addition to observed high levels of park-and-ride demand at Greenbelt station and significant congestion on parallel highway routes, suggests that additional consideration should be given to extending the WMATA Green Line. A modest extension north of the Washington Beltway would allow potential transit customers to access a park-and-ride facility without having to negotiate the congested I-95/I-495 interchange. Opportunities could include:

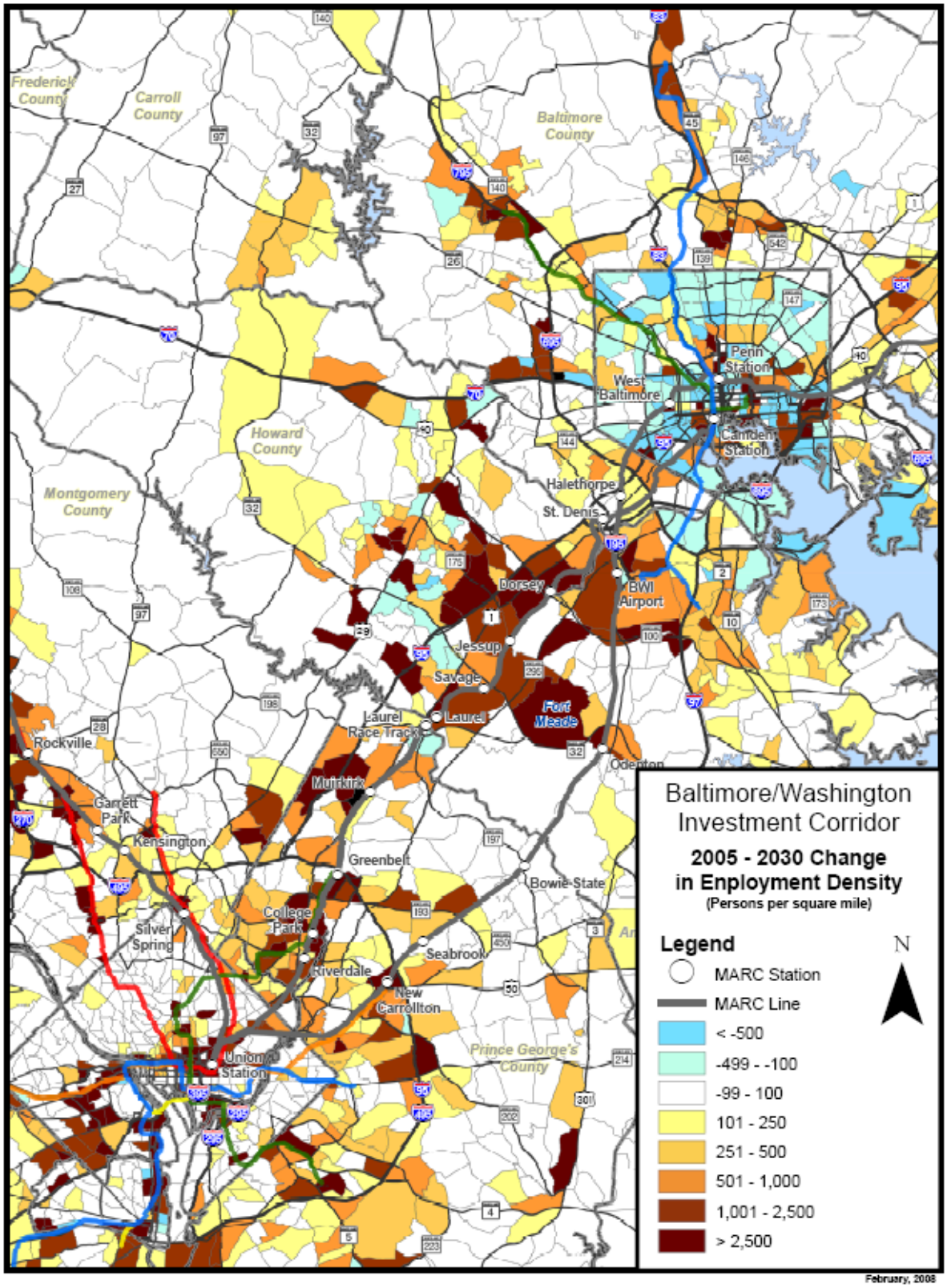
- Perform an alternatives analysis, with detailed travel demand modeling, for a high-capacity transit facility between Greenbelt and Laurel. The study area should include Columbia in the travel shed. Key objectives of this analysis would be to assess the relative effectiveness of extended heavy rail service or improved Camden Line commuter rail service on meeting the demand for transit in the corridor.
- Explore impact of improved MARC Camden Service as interim or baseline alternative.

Other Capital Investments

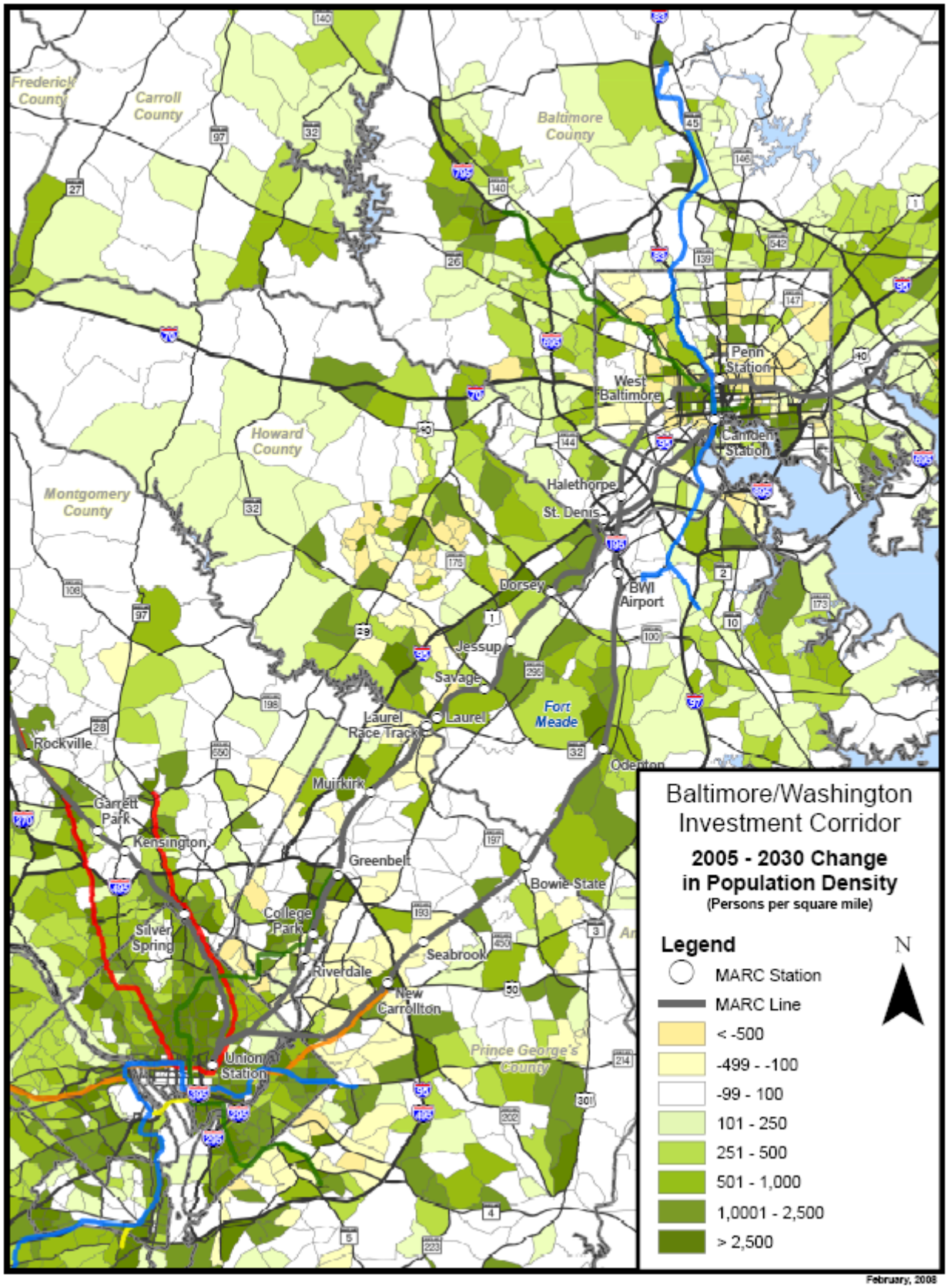
Identify opportunities for transit priority treatments in existing and planned road projects between Odenton and Columbia. Transit demand in this corridor is expected to grow rapidly and there is little existing service. This may include provisions for future dedicated transit or transit/HOV lanes on planned roadway facilities.

Appendix A – Population and Employment Exhibits

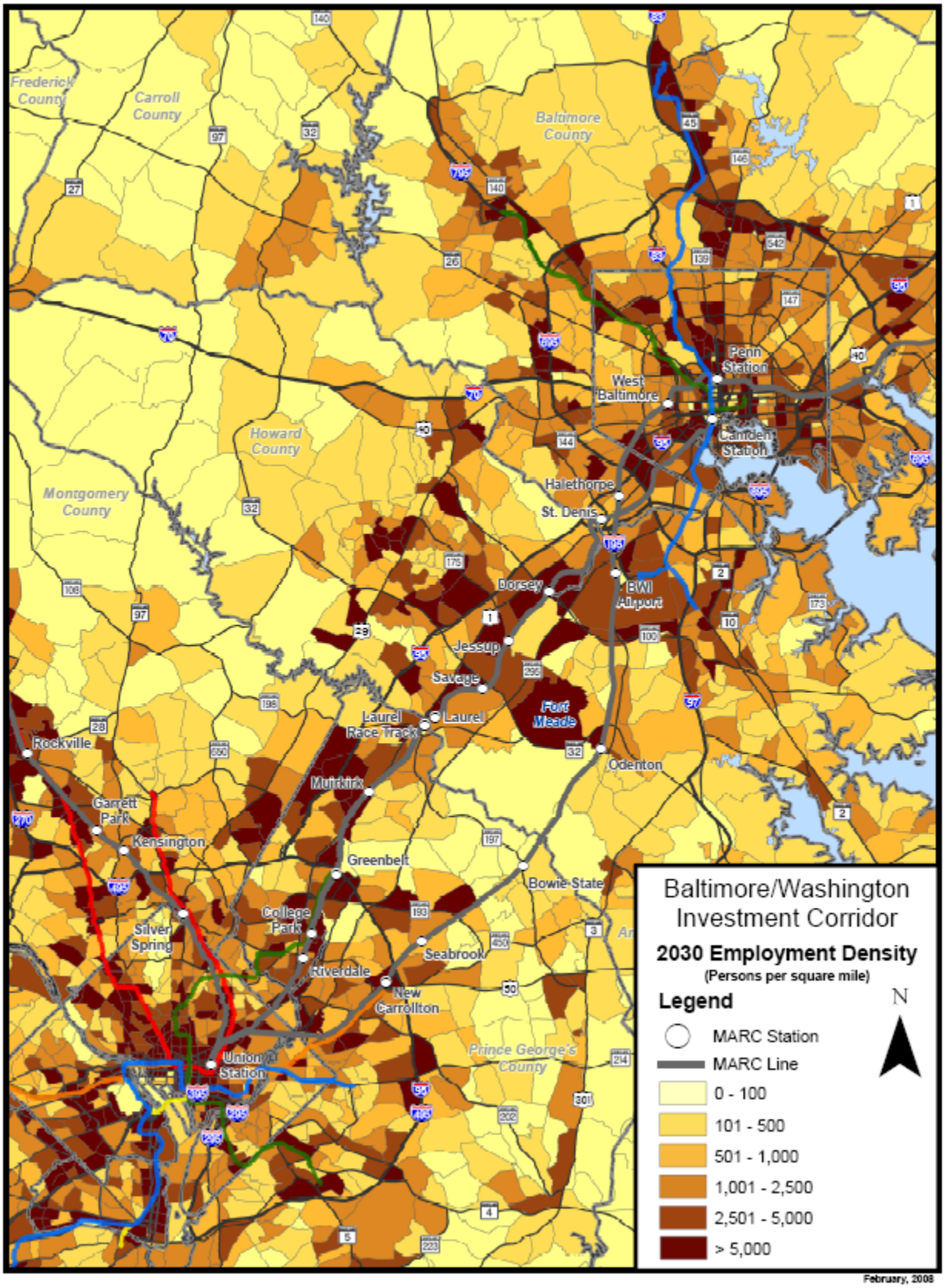
Change in Employment Density (2005 – 2030)



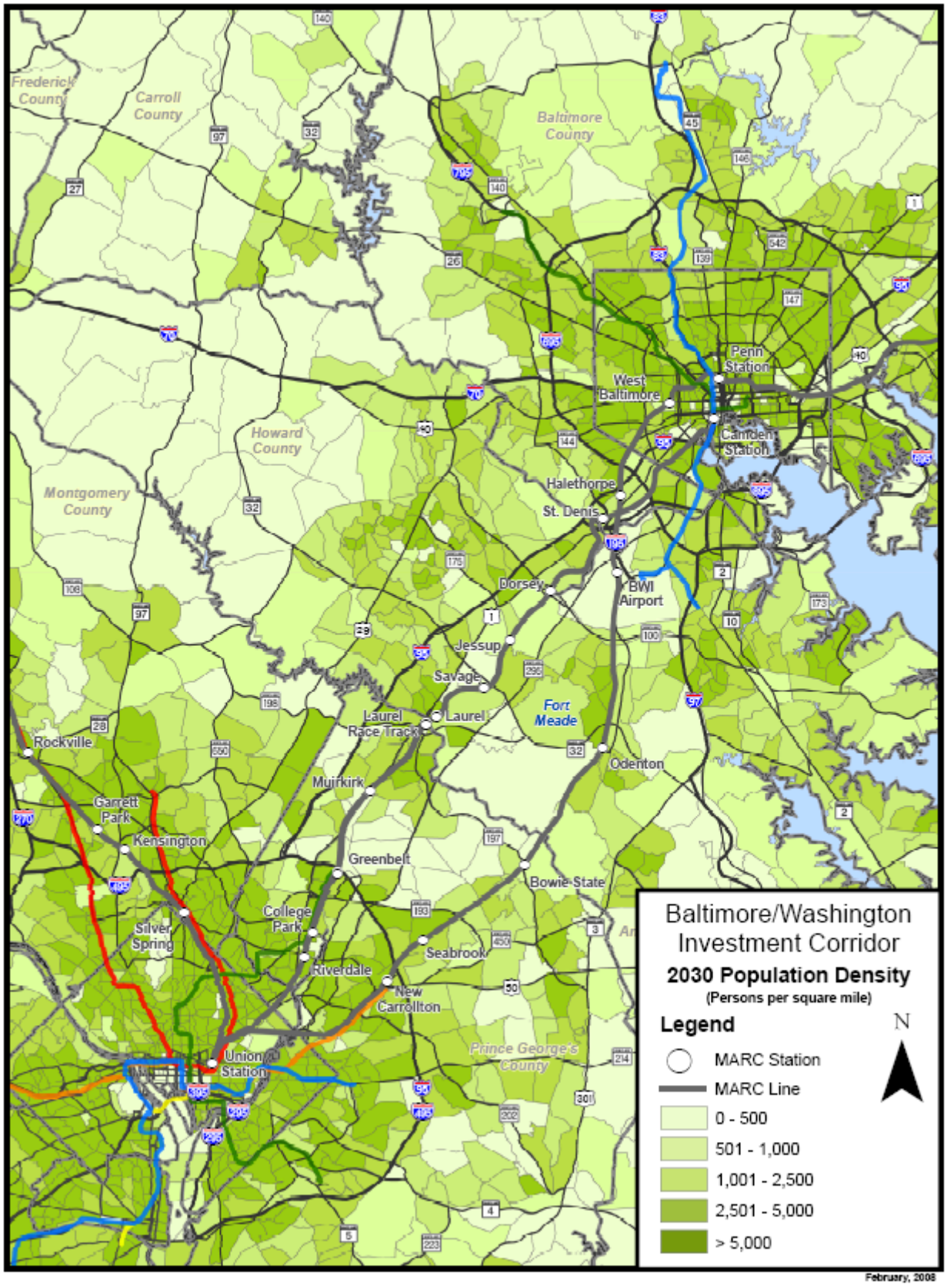
Change in Population Density (2005 – 2030)



2030 Employment Density



2030 Population Density



Appendix B – Rail Thresholds

Pushkarev et al. suggested several volume-related criteria to assess whether rail transit investments might be warranted. Those criteria include:

- Possibility of attaining adequate passenger space and service frequency;
- Possibility of attaining labor savings compared to bus operations;
- Possibility of saving energy compared to modes previously used;
- Possibility of attaining land savings compared to modes previously used; and
- Level of investment per unit of service provided.

They used these criteria to develop rail transit thresholds for low cost, medium cost, and higher cost rail transit. Their thresholds are presented in the second-from-left column in the table below.

Pushkarev Rail Transit Thresholds and Equivalent Peak Period Volumes

	Pushkarev Rail Threshold (passengers-mile/ route-mile)[1]	Implied Peak Hour Volume (passengers/hour/ direction)[2]	AM Peak Period Volume (passengers/hour/ direction)[3]
LRT-1	4,000	1,000	2,500
LRT-2	7,200	1,800	4,500
LRT-3	13,600	3,400	8,500
Heavy Rail-1	15,000	3,750	9,375
Heavy Rail-2	24,000	6,000	15,000
Heavy Rail-3	29,000	7,250	18,125

The thresholds in the far right-hand column above can be interpreted to imply that, for example, at least 2,500 riders are needed in the peak direction during the three-hour peak period to justify LRT-1 (a low cost LRT line) along a segment of a corridor. It should be noted that a line with fewer riders might still be justified based on other criteria or considerations.

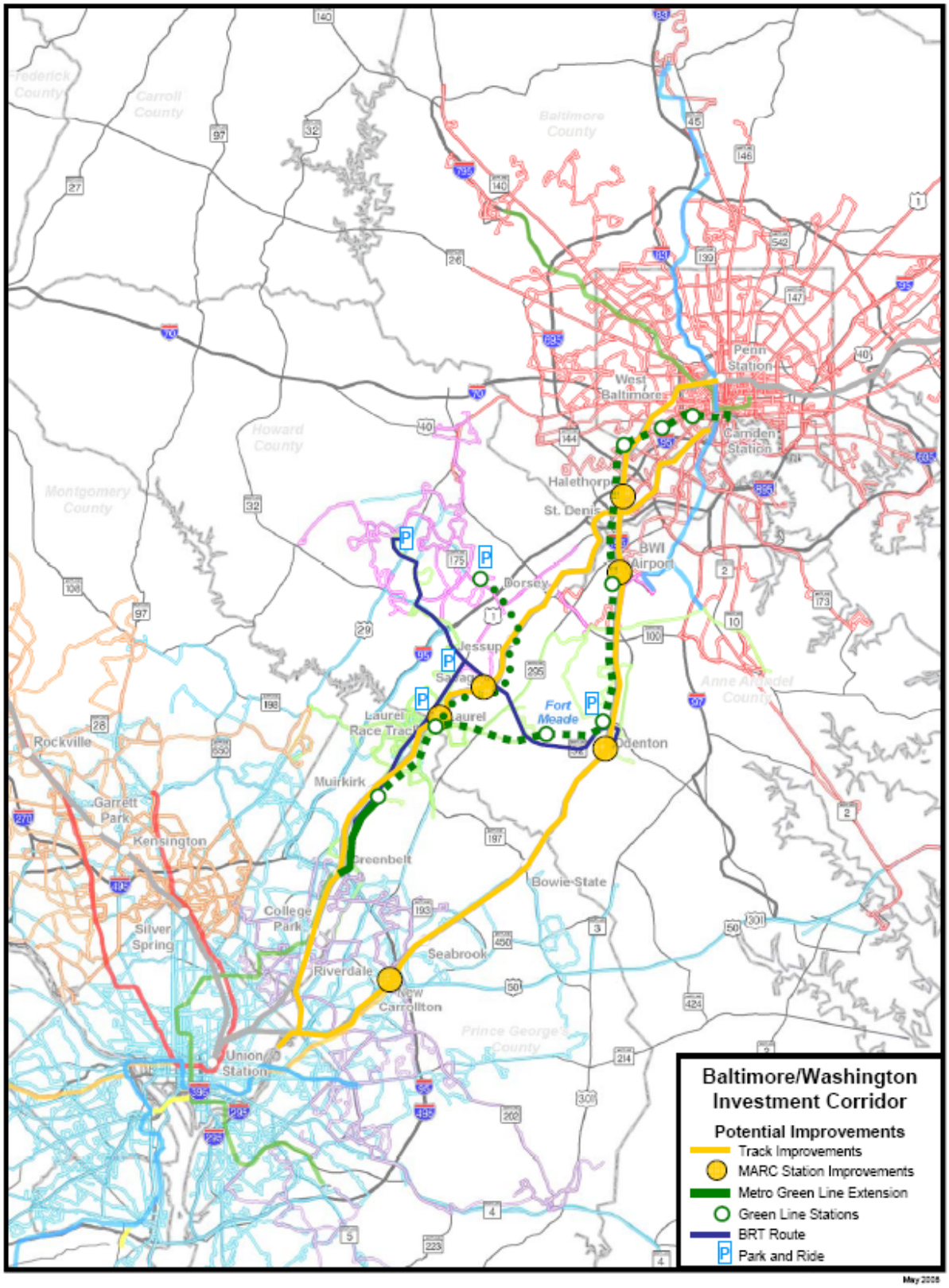
Pushkarev Rail Investment Definitions[4]

Rail Investment Classification	General Definition	LRT Specific Definition	Heavy Rail Specific Definition
1	Low cost	LRT at grade	Heavy rail elevated
2	Moderate cost	LRT w/ considerable grade separation	Heavy Rail w/ 1/3 in tunnel
3	Higher cost	LRT w/ up to 1/5th in tunnel	Heavy Rail in tunnel

[1] Pushkarev, B., J. Zupan, & R. Cumella, *Urban Rail in America: An Exploration of Criteria for Fixed-Guideway Transit*, 1982.
[2] Assumes 10-mi corridor, 4-mi average travel distance and 10% peak traffic share typical of US LRT, per Demery et al., 2005.
[3] 30-40% of one-way traffic during busiest three hours moves during the busiest hour, per Demery et al., 2005 (40% was assumed in the analysis).
[4] Demery, L., J. W. Higgins, M. Setty, "Traffic Density Thresholds for Rail Transit: A Retrospective," Publictransit.us Special Report 2, 2005.

Appendix C – Cost Estimates

Map of Potential Improvements



WMATA Green Line Extension

Alignment

The capital costs for the Green Line extension were developed from very conceptual alignments drawn over aerial photography obtained from Google Earth Pro. The alignment begins just north of the Greenbelt Metro station, where the Metro tracks enter the storage yard, and extend at-grade along the east side of the CSX right-of-way until descending into a short tunnel to an underground or depressed station near the future alignment for the Intercounty Connector. This location will provide excellent accessibility from the US 29 corridor via the ICC, the I-95 corridor, and the US 1 corridor.

The alignment then continues at-grade along CSX until again descending into tunnel under Laurel to a downtown station. Emerging back to at-grade, the alignment follows existing roadways and MD 32 to a station at Ft. Meade, then turning north to follow the west side of the Amtrak right-of-way to a station at BWI Airport. For the option to downtown Baltimore, the alignment continues along Amtrak to Wilkens Avenue and follows Wilkens to the final station at Camden Yards and the Charles Center Metro station, forming part of the Yellow Line of the Baltimore Regional Rail Plan.

The alternative to Columbia extends north from Laurel to MD 32 and follows MD 32 and US 29 to a station in downtown Columbia.

Stations

New stations are proposed for Muirkirk, Laurel, Ft. Meade/Odenton, Arundel Mills, BWI Airport, Arbutus, Wilkens Avenue, and Pratt Street, connecting with the existing Charles Center Metro station.

Operating Plan / Vehicles

Travel Time

Travel times assumed an average speed of 40 mph, accounting for station dwells, acceleration and deceleration, and some civil speed restrictions from curves.

Headways

Headways for estimating vehicle requirements were presumed to follow existing Metrorail strategy of reducing headways at outer stations by short-turning trains. (Only every other Red Line train travels to Glenmont during peak periods, for example.) For the Muirkirk extension, 6-minute headways were assumed. For all other stations, 12 minute headways were assumed.

Vehicle Requirements

The following table indicates the additional revenue vehicles necessary to operate the extension:

Additional Metrorail Vehicles Required for Different Extension Lengths of the Green Line

Metro extension to:	6 min headway	12 min headway	15 min headway	18 min headway
Muirkirk	18	12	12	6
Laurel	48	24	18	18
BWI Airport	60	30	24	24
Baltimore	72	36	30	24

20% spares were added for costing purposes. The shaded headways were assumed.

Feeder Bus
No costs were included for additional feeder busses to the stations.

Capital Cost Estimates
Capital cost estimates were developed using the same general methodology as was used for other Maryland fixed-guideway projects, following FTA guidelines for cost categories and reporting. Heavy rail unit costs were used derived from experience with comparable systems. Typical construction types were used throughout the alignment. Additional assumptions include:

- Two track guideway of similar design criteria as existing Metro.
- Stations with 600-foot long platforms to accommodate eight-car consists, similar to the existing Metrorail. Station size and facilities similar to the existing Metrorail.
- Assumes the same car as existing Metrorail.
- Assumes a storage yard for 60 vehicles and space for inspection and maintenance. All heavy vehicle repair is assumed to take place at existing Metrorail shops.

The following table lists the capital cost estimates for different lengths of the Green Line extension:

Conceptual Capital Costs for Green Line Extension

Metro extension to:	Length from Greenbelt	Capital Cost
Muirkirk	4.4	$660 mil
Laurel	7.6	$1,300 mil
Columbia	18.4	$2,475 mil
BWI Airport	23.0	$2,700 mil
Baltimore	31.3	$4,000 mil

Costs are not incremental – all costs in year 2007 dollars

MARC Commuter Rail

Capital costs for MARC alternatives were derived from the MARC Investment Plan 2007, including any improvement within the BWIC corridor and eliminating any physical improvement outside of the corridor or any operational improvement that would not benefit the BWIC corridor directly. The following tables describe the general capital improvements included in the cost estimates and the incremental costs for each level of improvements.

Improvements Proposed by the MARC Growth & Investment Plan for the BWIC Penn Line

	2010	2015	2020	2035
Track Capacity improvements		4 tracks W. Balt. to Odenton	4 tracks Odenton to Landover Rehab B&P tunnel	Washington Union Station improvements
Service frequency and capacity improvements	Lengthen trains Add peak, evening, and weekend service	15-20 min peak 30 min off-peak	Add limited stop service aimed at BRAC and airport	Optimize to meet demand New rolling stock
Parking increases	Station parking expansion south of Baltimore – Phase 1	Station parking expansion south of Baltimore – Phase 2		Where needed
Station improvements	Station Platform lengthening	Rebuild BWI Relocate W. Balt. Add platform at New Carrollton New E. Balt. Improve Odenton	Improvements to accommodate 4 tracks at Bowie State, Seabrook, and New Carrollton	
Capital Cost	$80 mil	$740 mil	$710 mil	$290 mil

Costs are incremental – all costs in year 2007 dollars

Improvements Proposed by the MARC Growth & Investment Plan for the BWIC Camden Line

	2010	2015	2020	2035
Track Capacity improvements		3 tracks Savage to Jessup	Double tracks from Alexandria Branch across Anacostia River 3 tracks Hyattsville to Greenbelt 3 Tracks Brentwood - Hyattsville	Additional 3rd track
Service frequency and capacity improvements	Lengthen trains Add midday train	Add peak trains	20 min peak Limited midday service	15 min peak Additional midday Start weekend service New rolling stock
Parking increases	Where possible	Savage, Muirkirk	Dorsey, Laurel Racetrack	Where needed
Station improvements	Cosmetic improvements	New Camden Station bldg Improved bus bays at Savage	Laurel Racetrack Close Jessup and St. Denis	
Capital Cost	$55 mil	$125 mil	$125 mil	$95 mil

Costs are incremental – all costs in year 2007 dollars

Bus Rapid Transit – Odenton, Columbia, Greenbelt Connections

Capital cost estimates for a bus rapid transit (BRT) line that connects Columbia and Odenton with the Greenbelt Metrorail station via US 1 were developed using the same general methodology as for BRT projects in Baltimore and Washington. The alignment would generally follow MD 32 between Columbia and Odenton, with service between the two areas, and via US 1 to Greenbelt Metro Station with BRT service from both Columbia and Odenton.

Alignment

The alignment between Columbia and Odenton would generally be within the median of MD 32, transitioning out to serve Ft. Meade. At the interchange with US 1, the BRT would connect with a new guideway south to the Greenbelt Metro station. Where feasible, the BRT guideway might be located within the median or service might run along the shoulder of the existing road. Through congested areas, and where no median or shoulder exists, dedicated lanes or lanes shared with turning traffic might be possible. Detailed engineering was not performed for this exercise. Given the congested nature of the US 1 corridor, constructing a north-south BRT guideway that achieves fast and reliable service would be challenging.

Stations

Seven stations were included in the BRT capital cost estimate: Columbia, Ft. Meade, Odenton, Savage, North Laurel, Laurel, and Muirkirk. Five of those would have parking facilities as well.

Operating Plan / Vehicles

The assumed operating plan includes three routes to serve both the north-south and east-west trip patterns:

4. Columbia to Odenton via Ft. Meade, and return.
5. Columbia to Greenbelt Metro station (or most northern Green Line station), and return.
6. Odenton/Ft. Meade to Greenbelt Metro station, and return.

Capital Cost Estimates

Capital cost estimates were developed using the same general methodology as was used for other Maryland BRT projects, following FTA guidelines for cost categories and reporting. BRT unit costs were used derived from experience with comparable systems. Typical construction types were used throughout the alignment.

The estimated capital cost for all three BRT routes (24 miles) is $295 - $440 million (in 2007 $), but could be more depending on the amount of roadway reconstruction and ROW. For the portion between Columbia and Ft. Meade/Odenton (via MD 32), the capital cost is estimated at $120 - 185 million (in 2007 $), depending on extent of new construction on MD 32. The capital cost for the other segment (Savage to Greenbelt via US 1, connecting to MD 32) is estimated at $175 - 255 million (in 2007 $), depending on extent of new construction along US 1. All costs can be reduced by using existing roadways for some or most of each alignment at the expense of travel time, reliability, and ridership.

Appendix D – Travel Time Comparison

Comparison of Travel Times by Mode

Travel Time to Gallery Place Metro from:	Miles	Penn Line	Camden Line	Green Line Extended
Greenbelt	9.8		38	25
Seabrook	11.0	26		
Muirkirk	13.5		43	32
Bowie State	16.0	33		
Laurel	17.6		49/39	37
Savage	19.6		57/47	43
Odenton	21.3	40/31		
Jessup	21.8		63	
BWI Airport	26.8	48/37		49

40/31 = local/express
Miles = straight airline distance between Gallery Place and listed station
Penn and Camden Line travel times includes 7 minutes from Union Station to Gallery Place Metro

Overall Assessment:

1. Penn Line is faster than Green Line because of higher maximum and average speeds and the ability to operate express service.
2. Green Line extension would be faster than existing Camden Line due to many tight curves and slow operating speeds.
3. Green Line can be extended to Muirkirk with little impact to MARC service. If extended north of Muirkirk, tradeoffs between Green Line and MARC service increases the further north the Green Line is extended.

   However, a Green Line extension might provide more accessibility to/from the corridor and those areas served by Green Line stations, such College Park, West Hyattsville, and north side of DC. Some passengers may find it more convenient to ride the Green Line than MARC if it doesn't require a transfer to reach their destination.