

Washington D.C. by Rail

Hubert H. Humphrey School of Public Affairs
University of Minnesota

Rebecca Barney, Xinyi Wu, Josh Pansch

December 2017

Abstract

Rail transit in the nation's capital is important for government leaders, tourists and residents in a rapidly growing area. In this report we review Washington D.C.'s Metro System, providing context, financial and spatial analysis, comparing it to similar metro systems, reviewing its Strengths, Weaknesses, Opportunities, Threats and providing recommendations based off of our findings. The Washington D.C. Metro is beset with a lack of dedicated source of funding while its expenses are growing faster than its revenues, resulting in a system that is at risk of cutting service and jeopardizing safety on aging infrastructure. We evaluate possible dedicated funding systems that Washington D.C. could use to support the system into future development. The Washington DC Metro serves both the district and the suburban populations surrounding it. We review the spatial service of the system, evaluating population density, household incomes, unemployment rates, diversity and future population growth. We provide a comparison of Washington D.C.'s Metro System to Boston's Metro system, evaluating its regional service, the challenges they face and how they plan on addressing them. We conclude with our recommendations for locating dedicated sources of funding, developing future connections to address equity throughout the system, investing into updating and maintaining technology for automated vehicles, and a complete safety review on the system to reduce the risks of accidents occurring in the future.

Table of Contents

Abstract	1
Table of Contents	1
Introduction	2
Fiscal and Political Context	4
Spatial Analysis	6
Peer Comparison	11
SWOT Analysis	14
Recommendations	16
Conclusion	17
Works Cited	19

Introduction

Transit in Washington D.C.

Transit in the Washington D.C. metro area is critical to not only the local community but also to the rest of the country. The national capital employs more than 237,000 federal or district employees and has more total jobs than it has residents. This high demand to get into the metro area for work creates a need for a high quality transportation system. Washington D.C. not only is important for employment but also for tourism. Last year there were more than 22 million tourists that visited the Washington D.C. area. These visitors demand a high level of accessibility when they arrive as there are hundreds of places to visit. The transit system is responsible for fitting an effective and equitable system of transportation into this unique environment for these various users.

Washington D.C. is the second richest city in the United States where “Half of the richest counties in America are roughly an hour away from the capitol.” (Lerner, 2017). Traffic is a big concern in area with a growing population in the suburbs and a concentration of jobs in the urban center. Recent strategy to implement congestion charges won’t be the only strategy needed to improve congestion and accessibility. Along with this, a highly effective transit system is needed to get mass amounts of people to and from destinations. The current rail system stretches out into these suburban locations but recent maintenance issues, service decreases and areas of D.C that aren’t served well have created a drop in ridership (Figure 1). Metrorail (Washington D.C. Metro subway) must implement new funding and management strategies to improve its credibility for new and existing riders.



Figure 1. Metrorail ridership since inception

Context

Washington D.C. is the most educated urban area in the United States (Reuters, 2006). Several colleges and many young professionals are attracted to the area to start their careers. Fewer in this generation are owning their own cars and many demand effective public transportation. The population of D.C. is made up of 48% black, 40% white, 5% Asian, and 7% other (American Community Survey, 2016). From 2010 to 2016, population has grown more than 13% (United States Census Bureau, 2016). The urban area of D.C. is a young, diverse and growing area with a pressing need for rail transit it can rely on.

The Washington D.C. Metro runs 118 miles of track serving 91 stations across the system (Metro Facts, 2017). 38.3 miles, and 40 Stations are within the District, while 38.3 miles and 26 stations serve Maryland and 41 miles and 25 stations serve Virginia (Metro Facts, 2017). It is the 3rd busiest rail system in the United States, after New York and Chicago (APTA, 2016). Metrorail serves 639,000 passengers per day (Metrorail Boarding's, 2016). In the transit agency in the D.C. area, the bus system is named Metrobus and the subway is named Metrorail.

There are several different types of transit in D.C. and the surrounding area. There is the subway in D.C. along with a local bus and streetcar system, there is train service from Maryland and Virginia, and cities outside of D.C. have their own local bus service. Metrorail relies on each of these forms of transit to reach a broader travel shed and increase its ridership and effectiveness. When looking at Metro specifically, the bus system still carries a majority of total Metro passengers. 60% of daily passenger boarding's are on bus and 40% are on rail (Metro Facts, 2017). The fare structure of Metrorail and Metrobus are not well connected. When transferring from a bus to the subway or the subway to a bus an additional fare is required. Transfers qualify for a \$0.50 discount but only if a smart card is used within a two hour window. Fares for Metrorail are determined by station entrance and exit and based on distance. Fares can range from \$2.15 - \$5.90 and are some of the most expensive in the country.

According to the 2016 ACS, 37% of commuters in D.C. use public transportation and only 34% of commuters drive alone to work. This compares to the broader MSA (Metropolitan Statistical Area) where 66% of commuters drove alone to work, and only 14% took public transportation. Public transit is used at a much higher proportion in the city and transit needs to be concentrated there.

History

Planning for the Washington Metro began in the 1950s, and construction began in 1969 (Schrag, 2006). From the beginning there were disagreements over how to best design future transportation in the D.C. area. The initial designs for transportation in Washington DC was a massive system of highways (Schrag, 2006). Transportation planners and engineers ended up deciding that subway was needed and the first segment of the Red line was built in 1976 with new segments being added to the system regularly nearly every year a decade after, and continuing to build upon it at regular intervals with the newest expansion being the Silver line which opened in 2014 (Metro Facts, 2017). The architecture of the stations was designed by Harry Weese, who aimed his designs to be the antithesis of New York's Subway (Carter, 2016). The architecture of the Washington DC Stations are well known and iconic to the Metro system.

Fiscal and Political Context

Funding Structure and Sources

Sources of funding and the management structure of Metro creates challenges to building an effective and equitable transit system. The challenges faced by Metro are unique and not seen across other agencies in the country. In spite of this, the community still uses the rail system to a high degree and leadership at Metro is putting new plans in place to create a reliable funding structure to support improvement and expansion of the transit system into the future.

Funding of Metro is made up of fare revenue and contribution from federal, state and local partners. Similar to the transit system in New York City, Metro gets a big portion of its revenue from farebox recovery. Metro operating expenses are made up of 52% fare and other local revenue while state and local governments fund the other 48% (Metro Facts, 2017). A major difference from the Metropolitan Transit Agency (MTA) in New York City is that Metro doesn't have a dedicated source of funding. MTA has dedicated funding from road tolls, real estate taxes, payroll tax and a variety of other mechanisms. Metro doesn't utilize any of these and has relied on yearly appropriations from local jurisdictions to continue funding operations. This comes with a high level of risk as year to year approval of funding by different jurisdictions can be politically challenging.

The federal government, State of Virginia, State of Maryland, local counties and cities all fund and manage Metro. This is coordinated through elected members from each group to a board of directors and funding is determined by population density, ridership and location of stations (Puentes, 2004). This funding formula has caused ongoing contention that the formula is unfair and yearly appropriations are put at risk of not getting approved.

Metro has only one more year remaining of committed capital funding with a shortfall of \$15.5 billion in order to maintain a safe and reliable system (Metro Budget, 2016). Expenses are growing substantially faster than revenues and without a dedicated source of funding, local jurisdictions will need to decide between cutting service and potentially safety or contributing even more from their general sources of revenue.

The original system received \$3 billion in funding from the federal government and has been getting ongoing assistance from the federal government since. This makes sense since much of the system is used by federal government employees but it has caused a lack of urgency in finding a dedicated source of funding. Much of the funding that is currently going to Metro isn't coming from sources in the transportation sector. Local jurisdictions are pulling from their general funds to support their portion. This falls in line with precedent for funding transportation in general across the country. Many transportation financing structures are made up of funding mechanisms that rely on property taxes and sales taxes that aren't directly tied to road or transit use. While Metro hasn't found the political capital for a dedicated source of funding, other agencies have funding strategies that Metro could look to in the future.

Dedicated Sources of Funding

There are many forms of dedicated funding that Metro could look to. Some options that might make sense in the D.C. area include congestion pricing, sales taxes, parking taxes, land value capture, payroll taxes, property tax zones near stations, hospitality tax or tourist tax. Congestion pricing has been implemented in D.C. and has potential to expand to bring in additional revenue. There are examples in New York City, San Francisco and London where it has provided a helpful source of funding and has improved management of traffic in the area. Congestion pricing would incentivize people to use transit but full implementation could be difficult (Puentes, 2004). New York City and San Francisco have a tunnel and bridge system that create optimal locations for tolling where D.C. has many roads and entrances to the city limiting the effectiveness of congestion pricing. Previous examples and studies have shown that this strategy alone wouldn't meet the need and it would only be a piece of the funding puzzle (Puentes, 2004).

Another option that would make sense would be to capture additional tax revenue from tourism. Since this is a large piece of the economy in the region and some of the transit system has been largely built for tourists, at the expense of the local community, it would be fair to charge a tax for tourists to use the system. Much of the rail transit system isn't equitable for the community that needs it most. Stations in low income areas are spread out and are located near tourist areas in the urban core. In order to balance this, a tax could be implemented on tourists that are only temporarily using the system and don't rely on it for their livelihood. This could be implemented through a hospitality tax or other mechanisms centered on tourist activities in the region.

A third option for dedicated funding is seen in Seattle. The transit system has been largely funded through referendums passed by the community. A series of Sound Transit plans called for an additional tax to fund a large expansion of the transit system in Seattle. There is wide community support that has translated into political will. This organization and initiative is currently lacking in the Washington D.C. area. Seattle has made a statement that transit is important to their community. This level of agreement hasn't been made in the D.C. area and political leaders aren't forced to fall in line with the clear voice of the community. By passing Sound Transit three separate times (Sound Transit, 2017) there is little debate over funding transit. A grassroots campaign like this would establish support that political leaders would hear and eventually need to follow by creating dedicated funding for Metro.

This approach of local support wouldn't be completely new to the D.C. area as it has created local funding and support for the D.C. Streetcar and D.C. Circulator bus system. The community recognized the gap in the Metro system and decided to build and manage their own transit system through the District of Columbia Department of Transportation. This streetcar is a renaissance of an old streetcar system and was opened for operation again in 2016. This local initiative is an example of how D.C. can create a common vision for rail transit across the entire region.

Transit funding for Metro has many unique challenges. The unique structure including decision making authority from federal, state and local governments creates ongoing confusion

and stress on the stability of the system (. This lack of ownership of the system has created an obstacle to implementing a dedicated source of funding. Without political or community wide leadership the risk of funding gaps will continue and the reputation of a once successful transit system will deteriorate. The success of transit in the national capital is key not only to the local community but also to the country as a whole.

Spatial Analysis

Washington D.C. is a unique city in the United States as the city itself is Federal land outside of any state jurisdiction, however as a metropolitan area it still reaches past the federal district and into portions of Maryland and Virginia. In order to serve the entirety of the population functioning within the Washington D.C. metropolitan area Metro must cross into these areas as well. However, when looking at the actual extent of Metro, the system tends to sprawl much further than a typical subway metro system (Figure 2). Considering the length of the Metro system, it has very little network connectivity, each line functioning as to-and-from connection with a very low link to nodes ratio. The stops along the line are irregular in their density and spacing between each station and tend to become spread further apart the further away it is from the center of the district. While some stations have more regular spacing a half a mile apart, many stations can be two, sometimes three miles apart (Figure 2).

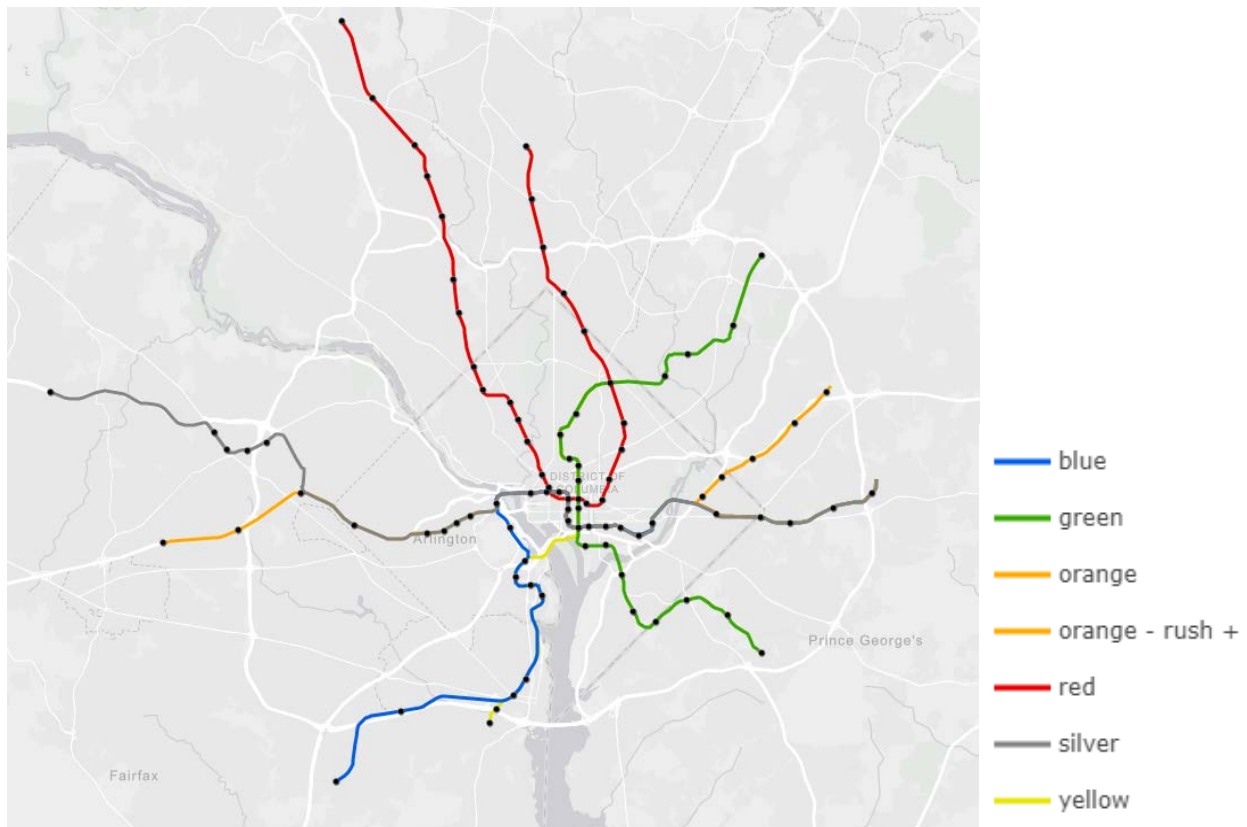


Figure 2. Washington D.C. Metro Lines

The areas reached by the Metro are a specific area of interest in terms of transportation, equity and development. When considering population density, the majority of the Metro serves areas with a higher density within the Washington metropolitan area. However, most of the Metro lines end in less dense areas, despite there being plenty dense areas nearby that Metro does not serve within the system (Figure 3). This is particularly relevant for the recent Silver Line and its extension which extends even further into less dense areas. While there has been a great deal of development along the first phase of the Silver Line, that development has not lead to as high of ridership as was predicted (Aratani, 2017). That being said, there has been economic improvement and growth near the stations within the first year of opening (Fogg, 2015). As the second phase of the Metro Silver Line connects to the Dulles International Airport, there have been concerns for development in the area being impeded by airport noise complaints (Foley, 2016). However, it is still too early to know whether or not the development along the Silver line will greatly impact the density in these areas (Aratani, 2017).

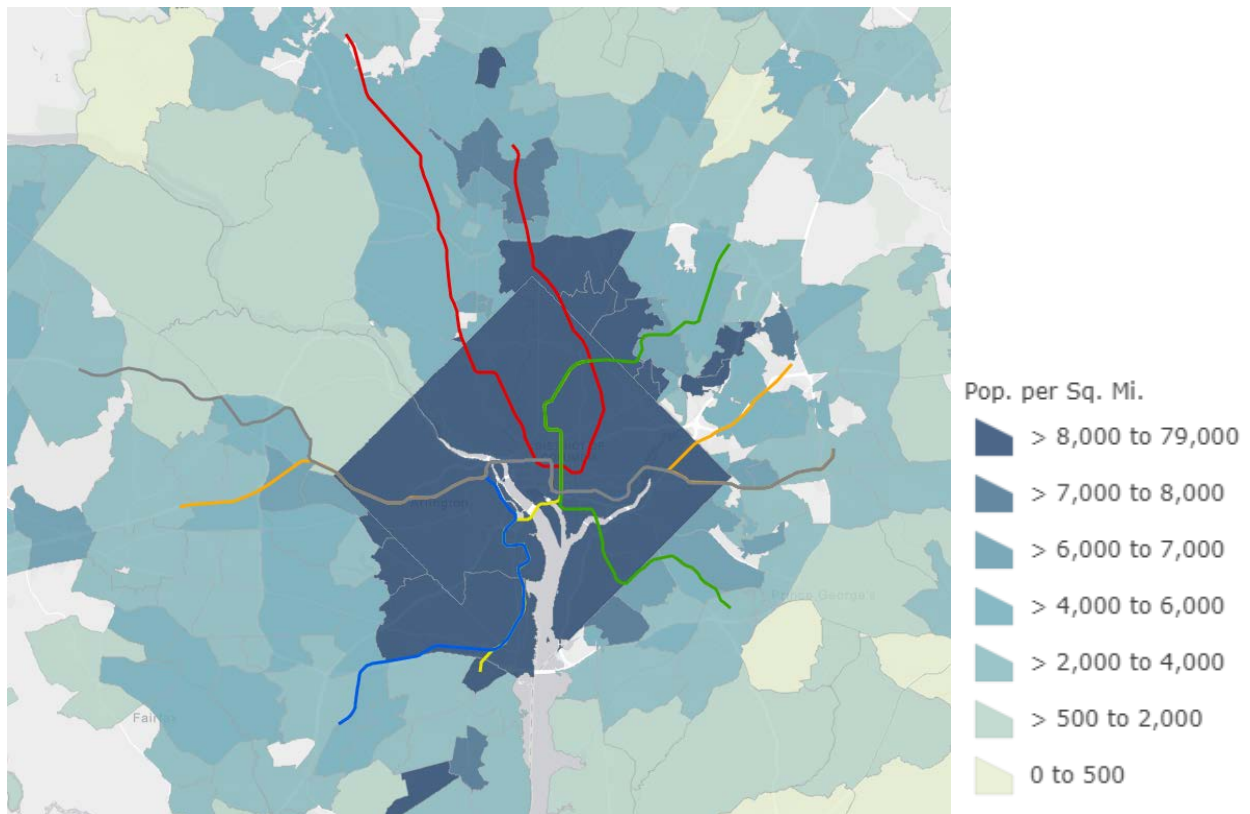


Figure 3. Population Per Square Mile, US Census Populated Places

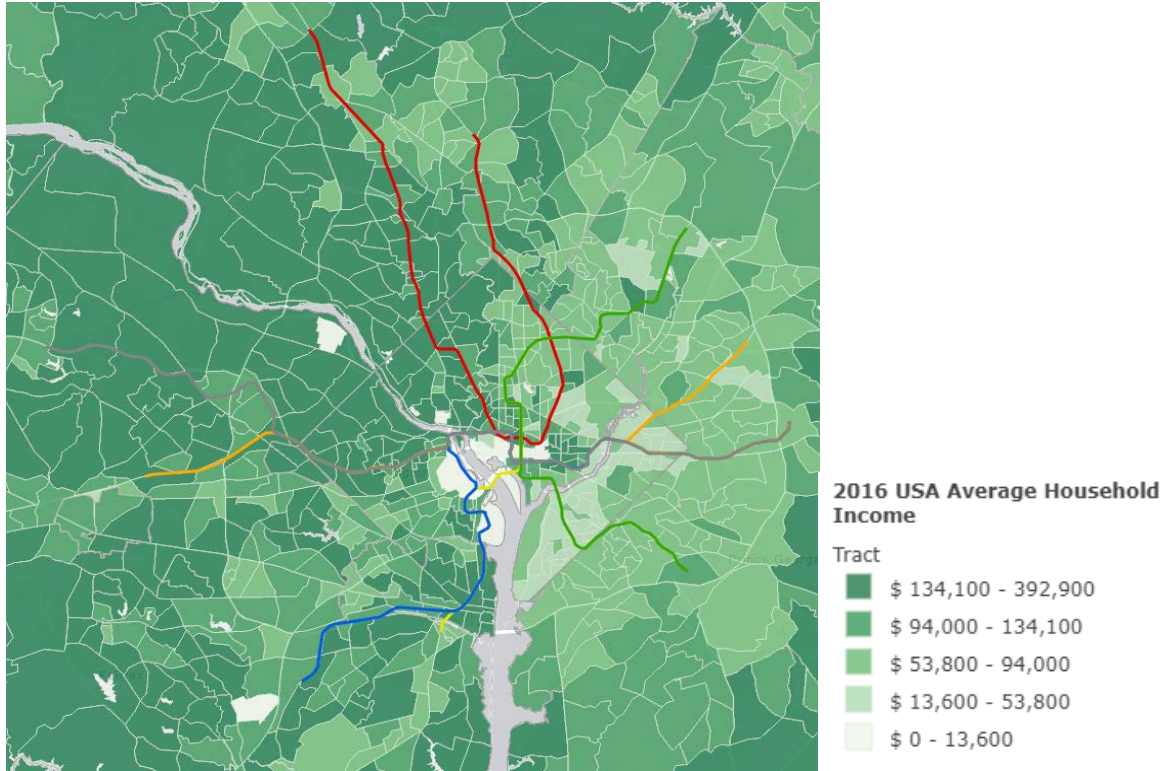


Figure 4. Average Household Income by Tract, US Census

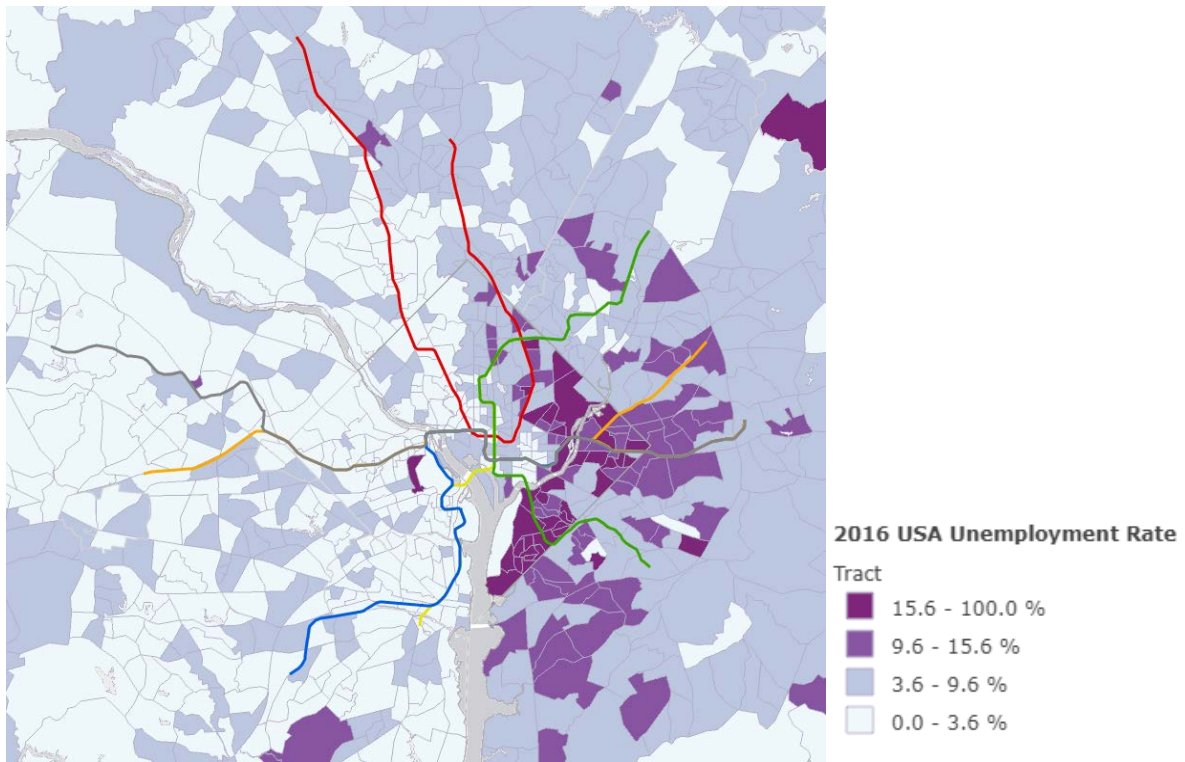


Figure 5. Unemployment Rate by Tract, US Census

The Washington DC metropolitan area is one of the richest cities in the country (Lerner, 2017). However, there is still a spatial divide between the east and west when it comes to wealth in Washington D.C. Much of the wealth is on the western side of the metropolitan area, with pockets of slightly less in the southwestern portion, in between the Blue and Silver lines (Figure 4). The majority of the lower income population for the entire metropolitan area, is on the eastern side of Washington D.C. proper.

This pattern can also be seen in the unemployment rates, where the highest rates are located inside of Washington D.C. proper and continue east into Maryland. The western side of the metropolitan area has a very low unemployment rate with the majority of the tracts in the area with a rate less than 3%, compared to tracts on the east side of the Potomac River with unemployment as high as 27% (Figure 5).

The east-west divide in the Washington D.C. metro area also continues when it comes to diversity and racial populations. There is an obvious east-west split in the percentages of white populations to non-white populations in the Washington D.C. metro area (Figure 6). Populations of Black or African Americans tend to be in the southeastern districts while Hispanic populations tend to be in the northeastern districts (District Mobility, 2017). It is also important to note that there is a reasonably large area in the southwestern portion in Virginia of non-white inhabitants, directly in between the Yellow and Blue rail lines (Figure 6).

Accessibility for non-white populations in the Washington D.C. metropolitan area is highly restricted when it comes to transit. The southwest portion of Washington D.C. has the longest average commutes in Washington D.C. proper, with trips taking about 46 minutes. (District Mobility, 2017). For many areas, the people inside of the district are more disconnected from the downtown than people in the suburbs. (Siddiqui et al., 2017).

Metro has missed the mark when it comes to equity largely due to under-serving people of color and accessibility for Washington D.C. proper residents. In the areas that it does serve, the stations tend to be further apart, for example along the southern leg of the Green line reaching into areas with the highest density of low income, high unemployment and people of color within the district.

Areas of future job growth are projected to be served by the Silver line but many other areas are currently underserved by rail transit. There is projected to be more jobs concentrated in the western half of the region between now and 2040 (Siddiqui et al., 2017). There is a pattern of minimal to reasonably large growth in the entire Washington DC metropolitan area in the coming years, with a pattern of growth occurring around already existing Metro lines (Figure 7). Future rail transit lines and stations should look to population projections to make planning decisions. Pockets of growth between the Blue and Silver lines will need an efficient connection to the system as well as pockets of growth between the Green and Yellow lines (Figure 7).

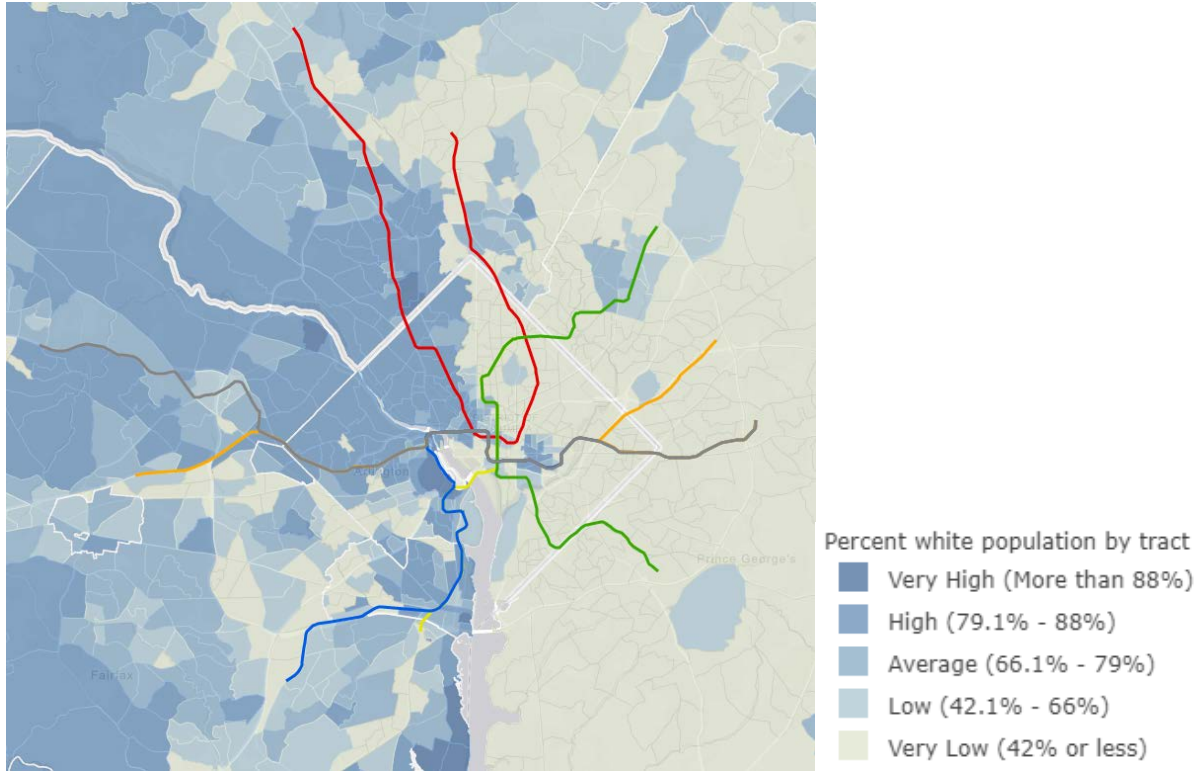


Figure 6. Percent White Population by Tract, US Census

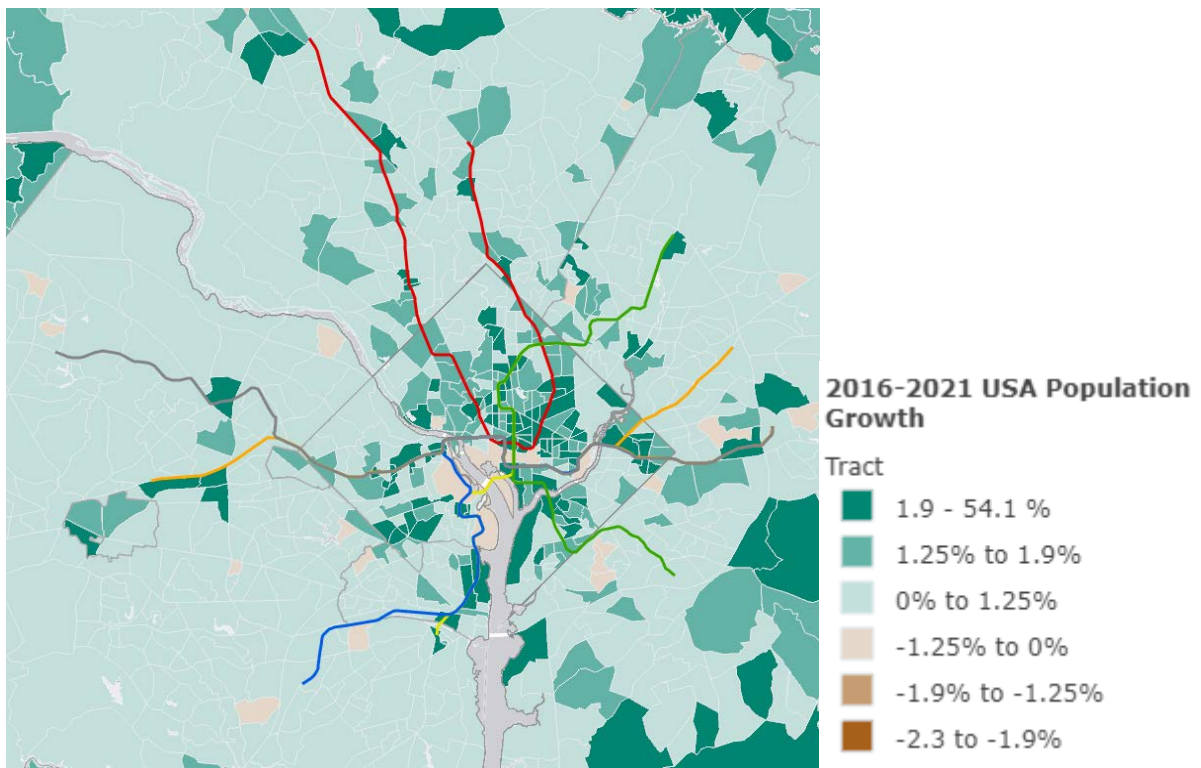


Figure 7. Population Growth 2016-2021, US Census

Peer Comparison

Comparing different transit systems across regions provides us with a better understanding of the operation and performance of each system. Among all the metro areas across the United States, Boston and Philadelphia have similar population, demographics, urban form, and climates as Washington D.C. As a result, we compare the transit performance of these three cities. Table 1 shows that, compared to Boston and Philadelphia, Washington D.C. and Boston have the similar amount of unlinked passenger trips, and Philadelphia has the lowest unlinked passenger trips (Federal Transit Administration, 2015). Washington D.C. achieved the highest level regarding fare revenue and transit mileage among the three cities. When it comes to operating costs, Philadelphia spent the lowest while Washington D.C. spent the highest expenses in transit. However, if controlled by transit mileage, the operating cost of Washington D.C. become the lowest among the three cities.

Table 1. Comparison of transit performances

City	Population	Fare revenue	Fare revenue (per capita)	Unlinked passenger trips	Transit mileage	Operating cost
Boston	4,181,019	584,488,768	139.80	403,734,144	4,132	3,002,177,384
Philadelphia	5,441,567	496,951,168	91.33	381,279,648	5,098	2,469,663,400
Washington DC	4,586,770	857,958,720	187.05	473,415,328	8,386	3,418,050,454

To provide specific implications for the transit agency in Washington D.C., we also conducted a detailed comparison between the transit systems of Washington D.C. and Boston regarding jurisdiction, services, funding, and future plans. At the end of this section, we summarize the gaps of performance between these two systems.

Washington Metropolitan Area Transit Authority (WMATA)

The major transit agency serving the Washington D.C. metro area is Metro created by the National Capital Transportation Agency (NCTA). The formation of Metro was based on the common agreements between multiple states. Its service covers regions across the District of Columbia, Maryland, and Virginia. As a result, directors from four entities composed the jurisdiction board of Metro: the District of Columbia, Maryland, Virginia and the Federal Government. Besides the board that oversees the management of the agency, Metro also has a General Manager who is in charge of the specific operational issues.

Metro provides bus and rail services covering regions in the District of Columbia, Maryland, and Virginia. Metro's bus system is the sixth biggest in the country, with 325 routes and 11,500 stations. The Metro rail system of Metro has six color-coded lines and 91 stations, serving approximately 600,000 passengers each day. The rail system in the Washington D.C. metro area has a typical radial system design (Figure 8). Most existing six railway lines connect different suburban areas with downtown Washington D.C., whereas the connections among

suburban areas are relatively lacking. Nevertheless, Metro is planning to open a new light rail line, the Purple Line, to allow passengers to transfer among the Red, Green, and Orange Lines in the suburban areas without going through central Washington D.C (WMATA, *Why Metro Matters?*).

Metro is in great need of funding over the next decade, but there is a large gap between the needed funds and available funds. Metro needs \$15.5 billion in the next ten years to maintain safe and reliable services. In order to improve and extend the services, about \$25 billion funds are needed. However, only \$1.25 billion capital need is being funded currently (WMATA, 2013).



Figure 8. Washington D.C. Metro Lines

To face the rising challenges of climate changes and the economics and population growth in the local region, Metro has launched a strategic plan named Momentum. This plan intends to fulfill the following main goals during the coming decade (WMATA, 2013):

- Maintain and improve the safety of the system, especially in cases of emergencies and extreme weather;
- Deliver fast, reliable and convenient services for passengers ;
- Increase the accessibility and mobility of the Washington D.C. metropolitan region by extending current lines and creating easier access to transit stations/stops;
- Secure the current funding to maintain financial stability while exploring opportunities for investment.

Massachusetts Bay Transportation Authority (MBTA)

The major transit agency serving the Boston metropolitan areas is MBTA. Unlike Metro, MBTA has a much simpler jurisdiction structure. Two government bodies oversee the MBTA:

the Massachusetts Department of Transportation (MassDOT) Board and the Fiscal and Management Control Board (FMCB). The MassDOT board is in charge of overseeing all transportation-related issues in Massachusetts, including public transit. The FMCB is in charge of overseeing and improving the management, finance, and operational issues of MBTA.

MBTA is one of the only transit systems in the U.S. that operate all five types of transit modes: bus, rail, commuter rails, ferry, and paratransit. According to the ridership data, 1.36 million trips were made with MBTA services during the weekdays of September 2017. Among these 1.36 million trips, 60% were made with the subway and 30% were made with buses. Similar to Washington D.C., the railway routes of Boston also has a radial design (MBTA: *Performance*, 2017) (Figure 9).

MBTA aims to maintain a balanced budget in each fiscal year. In other words, the budget spends and the revenues earned should be equal and any differences between these two are considered a deficit. In the fiscal year of 2017, MBTA earned \$1.94 billion revenues but spent \$2.02 billion, resulting in an \$80 million deficit (MBTA: *Performance*, 2017).

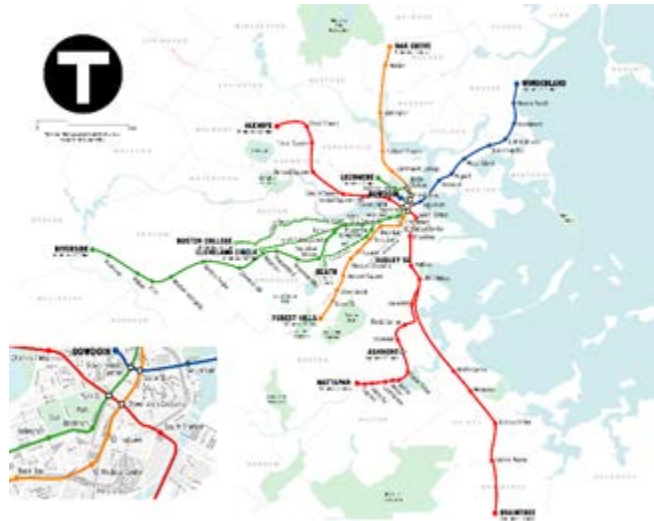


Figure 9. Boston Metro Lines

To cope with the rising need for transit service within the Boston metropolitan region, MBTA is planning to enhance its services by implementing the following projects (MBTA: *Improvements and Projects*, 2017):

- Enhance the Wollaston Station on the Red Line by implementing multiple new facilities and features (including elevators, escalators, and energy-efficient lighting, etc.);
- Install positive train control (PTC) to commuter rails. PTC can reduce the human errors in train operation, thus minimizing the accidents caused by collisions and derailments.
- Implement an easier fare-paying system: the Automated Fare Collection 2.0 (AFC2). This new fare-paying system allows passengers to pay their fares with smartphones and credit card at any door of buses and the Green Line light rail. Not only would this system

make fare paying more easily, it would also speed up the services of buses and light rails with the reduction of fare-paying times.

Gaps of performance between these two systems

Despite multiple traits shared by the two transit systems in Washington D.C. and the Boston metropolitan areas, there are still differences of performance existing between these two systems. The transit service in Boston does better regarding service diversity and financial management. To begin with, the transit systems in the Boston region has more diverse transit modes, some of which are not being provided in Washington D.C. Furthermore, compared with Washington D.C., the transit agency in Boston has a more developed financial system to maintain the balance between budget and revenues. This lack of financial management leads to a severe funding shortage in the operation and development of the transit systems in the Washington D.C. region. On the other hand, the transit system Washington D.C. does better jobs in planning and system design. First, Metro published a detailed strategic plan guiding the agency to maintain and improve the quality of service. Moreover, the Purple Line designed to connect suburban areas is currently being built in Washington D.C. Although Boston has a very similar system design which lacks connections between suburban areas, MBTA is not planning to build new lines to connect these regions.

SWOT Analysis

Strengths

Metro has strengths that make it appear to be a successful rail system. Ridership has been increasing steadily up until recent years. One of the key strengths of the agency is the ability to bring in a high portion of fare revenue. 64% of the Metrorail operational revenue comes from passenger fares (Figure 10). This gives the rail system a source of confidence and strong support of its operational expenses into the future. Another strength of the rail system includes its wide transit coverage. It has 118 miles of track that spread out into the outer areas of the D.C. suburbs. A last strength of the D.C. system is its newer strategy of concentrating growth around transit corridors. The Rosslyn-Balston corridor is a signature transit oriented development that can be copied across the D.C. area (Leach, 2004).

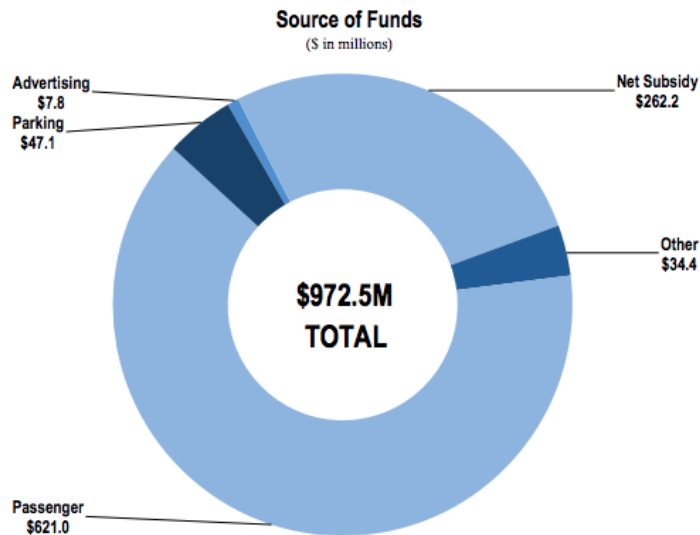


Figure 10. Metrorail Source of Funds- Operations

Weaknesses

One of the largest weaknesses of the Washington DC Metro system is their lack of equity when planning the design and function of the system. The Metro heavily under-serves the lower-income, non-white populations in the D.C. Metropolitan area, and in some areas of the city are more disconnected to the core than the suburbs are. These issues developed from a design goal to make the Washington D.C. rail commuter-oriented, focused on moving people in and out of Washington D.C.'s core and not so much for accessibility or functionality outside of suburban-urban access. In many areas that are transit dependent stations are spread apart forcing transit dependent population to use other forms of transportation to connect to the rail system. In a lot of ways, Washington D.C. is a prime example of a successful "bad" rail system.

Proper maintenance and repair is a major weakness of the system while also getting a lot of attention in the media. This stems from a lack of dedicated funding to create an ongoing stability and source of money to pull from when needed. Many transit agencies across the country have gaps in maintenance funding compared to their needs. Political leaders have little reason to make a stand for additional taxes to maintain rail systems. Rail expansion comes with a ribbon cutting while rail maintenance creates little in political incentive. Funding for maintenance is easily forgotten until accidents happen which is why it is especially important to have dedicated funding in support of the ongoing cost of a rail system. During times of crisis it is essential to have a reliable source of money to use to repair and get the rail system back into operation. Since this isn't available to D.C.'s Metro it will continue to be a weakness in the system compared to other systems across the country.

Opportunities

Metrorail has the opportunity to turn its ridership numbers around and better serve its community. The area can take advantage of its growing population and continue to build its fare

revenue to support funding. Continued growth will make more people rely on efficient public transit to get to jobs and other activities. Traffic can be very congested and recent work to implement congestion charges will make it even more important for future growth to have access to transit. Another opportunity for Metro is for a political leader in the nation's capital to lead on building momentum for dedicated funding. A strong political leader can make a name for themselves by being the one to fix the Metro funding issue. A final opportunity for Metro is to leverage the tourism dollars coming into the region. The D.C. region should use some of these dollars towards building a better transit system for its residents.

Threats

A threat on the success of Metro is the lack of an effective governance structure. This can be seen by the inability to spend available funding on the system even when critical failures continue to occur. Billions of dollars have been made available to Metro to make operational improvements following recent accidents but money has been left on the table. The ineffective governance structure and political climate has created roadblocks to effectively fixing the problems in the system. A board of directors consisting of multiple jurisdictions responsible to a diverse set of voters creates conflict and can limit their ability to agree. This will continue to threaten the success of Metro unless improved leadership and structure is put in place.

As maintenance issues continue to pile up the reputation and trust in the system is deteriorating. This will threaten the future success of the system unless it is quickly fixed. Those that live in the area without the income to purchase a car or use ride-sharing services like Uber need transit to be a reliable form of transportation.

Finally the current federal government doesn't seem likely to increase funding for public transportation, even in the nation's capital, so it will be important for Metro to find dedicated funding in the future. It can't rely on yearly appropriations from several jurisdictions and capital funding from the federal government. These are at an increasing level of risk of drying up and putting the Metrorail system in further jeopardy.

Recommendations

Based on the analyses, we make the following recommendations to maintain and to improve the quality of Washington D.C. transit.

- To guarantee adequate funding to maintain and improve the service, we recommend that Metro should work on ensuring stable funding sources and to cut budget costs. To achieve this goal, Metro could work with regional partners to develop multiple sources for future funding. Metro should also increase its efficiency and sustainability in operation and recruitment.
- Metro should also consider increasing the connectivity and equity of the system. The Washington railway system has a typical radial design, which sprawls into different suburban areas without interconnections among these areas. Moreover, the station

spacing tend to be farther on the east side of the region where low-income and minority population is clustering. This design further decreases the connectivity of the system in these areas. As a result, we suggest that Metro could add more railway lines and stations within the system's reach to improve accessibility within the District. Such an example would be the plans and advocacy for the Metro Purple Line, which connects the Red, Green, and Orange Lines.

- We suggest that more modern automated techniques and driverless trains should be implemented on the Washington Metro. Updating Metro's technology could benefit the system in two major ways. To begin with, an automated system can highly decrease the possibility of future collisions and similar accidents, thus increasing the safety of the service. Moreover, driverless vehicles saves budget on operational staff and frees more spaces onboard for passengers. Finally, studies have shown that a fully automated line can also increase the reliability of the system by 56%. Currently, the automation system has been equipped on some rail lines in D.C. We suggest that this new technology should be implemented more widely in the D.C. metro region.
- Addressing the aging infrastructure and its threat to the safety of Metro Passengers by completing a comprehensive safety review on the Metro system and taking immediate action to resolve areas of concern. Examples to safety concerns could be the "felt-like layer of Human Hair and Skin" that covers the tracks and poses a fire risk to the Metro Trains (Cheromcha, 2017).

Conclusion

Rail transit in Washington D.C is an important and unique system in the country. This transit system serves not only the local residents, but also a vast number of visitors travelling to D.C. Compared with other transit systems, this system is unique in many aspects due to the complex historical and political context of the D.C. region. Thus, an extensive and thorough analysis is necessary to understand the system and to provide complete recommendations for future development.

This report reviews the major characteristics of the transit system in Washington D.C., including an introduction to the region and the system, which serves as a background for further analysis. Within the overview the financial and political aspects of the system, we cover information regarding funding sources and structures of the agency, noting strategies in which dedicated funding could be developed. We offer a set of spatial analysis showing the relationships between the railway system and the people it serves, using the socio-economics features of the adjacent regions. We conduct a comparison of transit system between Washington D.C. and peer regions as a method of contextualizing typical development patterns. Based upon these analyses, the report identified the strengths, weaknesses, opportunities and threats of the transit system in Washington D.C, and provides recommendations for system improvements.

Our analyses show that transit in Washington D.C. does well regarding fostering development along the line, generating fare revenue and managing operational costs. The major limitations of the system are its lack of connectivity and equity in the design of the system. Also, the reliability and safety of the operation require improvements to recover the ridership after major accidents. To maintain and improve the quality of service, we recommend that the transit agency of Washington D.C. should devote efforts into stable funding sources, connectivity, automated technology, and equity of the system.

Works Cited

- APTA (2016). "Transit Ridership Report Fourth Quarter 2016" American Public Transportation Association. <http://www.apta.com/resources/statistics/Pages/ridershipreport.aspx>
- Aratani, Lori (2017). "Three years after opening the Silver Line struggles to attract riders" Washington Post. April 26. Accessed December 15, 2017
https://www.washingtonpost.com/local/trafficandcommuting/three-years-after-opening-the-silver-line-struggles-to-attract-riders/2017/07/29/a0c6cc06-6d74-11e7-b9e2-2056e768a7e5_story.html
- Carter, Elliot (2016). "How was it built- Metro" Architect of the Capital, hidden history in D.C.
<https://architectofthecapital.org/posts/2016/6/22/metro-under-construction>
- Census Reporter (2017). Census Data for the Washington DC Metropolitan Area
<https://censusreporter.org/profiles/33000US548-washington-baltimore-arlington-dc-md-va-wv-pa-csa/>
- Cheromcha, Kyle (2017). "Washington D.C. Metro Tracks Covered In 'Felt-Like' Layer of Human Hair and Skin, Officials Say" The Drive. November 22
<http://amp.timeinc.net/thedrive/news/16339/washington-d-c-metro-tracks-covered-in-felt-like-layer-of-human-hair-and-skin-officials-say?source=dam>
- District Mobility: Multimodal Transportation in the District. <https://districtmobility.org/>
- Eric Jaffe, (2015). "The Case for Driverless Trains, By the Numbers" City Lab.
<https://www.citylab.com/life/2015/04/the-case-for-driverless-trains-by-the-numbers/390408/>
- Fogg, Alan (2015). "One year later, Silver Line's economic impact already apparent" Fairfax County Economic Development Authority Press Release.
<https://www.fairfaxcountyeda.org/pressrelease/one-year-later-silver-line%E2%80%99s-economic-impact-already-apparent>
- Foley, Dennis (2016). "Officials weigh future impact of Metros Silver Line to Dulles" WTOP
<https://wtop.com/dc-transit/2016/05/officials-weigh-future-impact-of-metros-silver-line-to-dulles/>
- Facts and Usage Statistics about Public Transit in Washington DC- Baltimore, US.
https://moovitapp.com/insights/en/Moovit_Insights_Public_Transit_Index_USA_Washington_DCBaltimore-142
- Jaffe, Eric (2015). "The Case for Driverless Trains, By the Numbers" City Lab.
<https://www.citylab.com/life/2015/04/the-case-for-driverless-trains-by-the-numbers/390408/>
- Leach, D. (2004). Rosslyn-Ballston Corridor. The New Transit Town; Best Practices in Transit-Oriented Development. Chicago

- Lerner, Rebecca (2017). "The 10 Richest Counties In America 2017" Forbes.
<https://www.forbes.com/sites/rebeccalerner/2017/07/13/top-10-richest-counties-in-america-2017/#3759a7142ef3>
- Metro About (2017). <https://www.wmata.com/about/board/>
- Metro Budget (2016). <https://www.wmata.com/initiatives/budget/>
- Metrorail Boarding (2016). "Metrorail Average Weekday Passenger Boardings."
https://www.wmata.com/initiatives/plans/upload/2016_historical_rail_ridership.pdf
- Metro Facts (2017). <https://www.wmata.com/about/upload/Metro-Facts-2017-FINAL.pdf>
- Metro History (2017) <https://www.wmata.com/about/history.cfm>
- Metro (2013). Momentum, the next generation of Metro.
<https://www.wmata.com/initiatives/strategic-plans/upload/momentum-full.pdf>
- MBTA (2017). Transit performances.
<http://www.mbtabackontrack.com/performance/index.html#/home>
- MBTA (2017). *Transforming the T: Improvements and projects*. <https://www.mbta.com/projects>
- Nelson, P., Baglino, A., Harrington, W., Safirova, E., & Lipman, A. (2007). Transit in Washington, DC: Current benefits and optimal level of provision. *Journal of urban Economics*, 62(2), 231-251.
- Puentes, R. (2004). Washington's Metro: Deficits by design. The Brookings Institution Center on Urban and Metropolitan Policy: http://www.brookings.edu/~media/Files/rc/reports/2004/06metropolitanpolicy_puentes/20040603_puentes.pdf
- Reuters (2006). "Washington area richest, most educated in US: report" Washington Post
<http://www.washingtonpost.com/wp-dyn/content/article/2006/06/08/AR2006060800133.html>
- Schrag, Zachary M. (2006). "The Great Society Subway: A History of the Washington Metro" The John Hopkins University Press.
- Siddiqui, Faiz; Armand Emamdjomeh and John Muyskens (2017). "When commuting in the D.C. region, distance doesn't tell the whole story." The Washington Post.
https://www.washingtonpost.com/local/trafficandcommuting/when-commuting-in-the-dc-region-distance-doesnt-tell-the-whole-story/2017/04/15/b466fdb6-1ef1-11e7-a0a7-8b2a45e3dc84_story.html
- Sound Transit, 2017. <https://www.soundtransit.org/About-Sound-Transit>
- WMATA, 2017. *Why Metro Matters?* <https://www.wmata.com/initiatives/case-for-transit/index.cfm>