An Assessment of the Impact of the Baltimore Red Line on Job Accessibility

Submitted by data science working group based at Johns Hopkins University
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Introduction

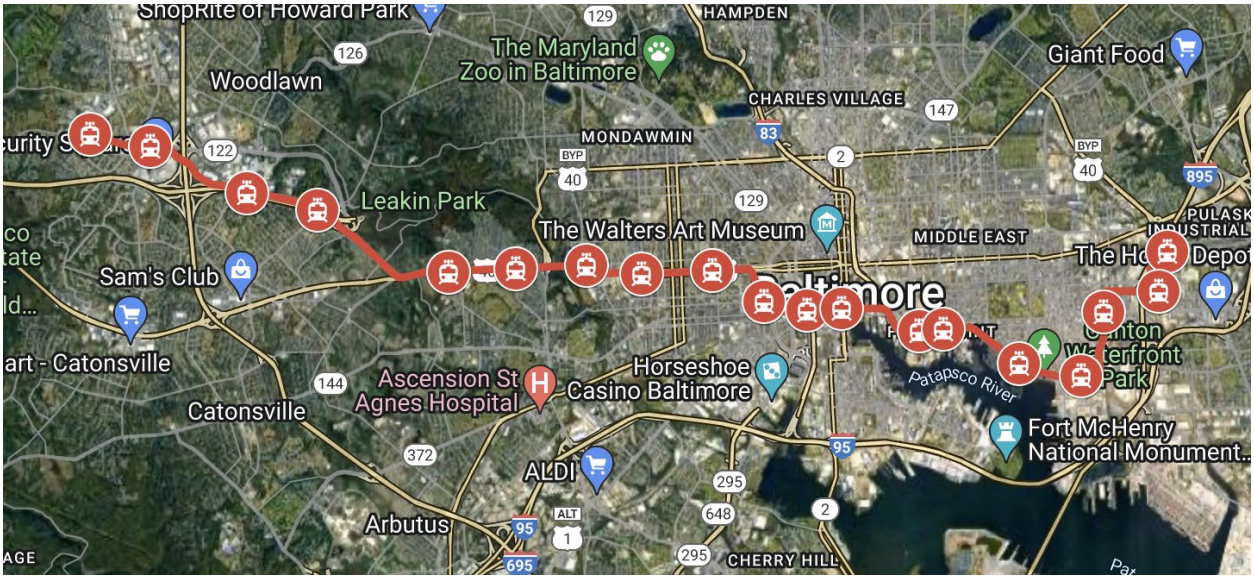

Figure 1. This figure outlines the stations and segments of the proposed Red Line[1]. The stations that constitute the Red Line include Centers for Medicare and Medicaid Services, Security Square, Social Security Administration, Edmonston Village, Allendale, Rosemont, West Baltimore MARC, Harlem Park, Poppleton, Howard Street/University Center, Inner Harbor, Harbor East, Fells Point, Canton Crossing, Highlandtown/Greektown, Bayview MARC, Bayview Campus, I-70 Park-and-Ride, and Canton.

Using data from Titus (2015), Bloom (2023) wrote, "With one in three Baltimoreans lacking cars, about one in five commutes on transit and with 21 percent of the city's population living below poverty line, transit remains essential to many families" (p. 111). However, in the Baltimore region, a stark disparity in transit accessibility underscores a pressing societal challenge: while all jobs in the region are accessible within an hour by car, only 9% are accessible within an hour by public transit (Bloom, 2023, Chapter 4; Baltimore Transit Equity Coalition, 2021). This inequity is felt most acutely by young adults, Black and Hispanic workers, women, families without cars, and lower-income individuals, highlighting a critical area of concern for urban development and social equity. Amidst this backdrop, the Red Line project emerges as a potential catalyst for bridging transportation and economic disparities prevalent in the city. Initially proposed as a 14-mile East-West light rail transit line, the Red Line aims to connect the Woodlawn area of Baltimore County to the Johns Hopkins Bayview Medical Center, traversing through West Baltimore communities, downtown Baltimore, Harbor East, Fells Point, and Canton. By linking to existing transit options like buses, the Light Rail, Metro, and MARC Train, the Red Line project aspires to create a more comprehensive transit system for Greater Baltimore.

[1] "Baltimore Red Line - Google My Maps." 8 Jul. 2021, https://www.google.com/mymaps/viewer?mid=1-nQTrR-62ggDsL5BaeBK20_X8wA&hl=en_US. Accessed 7 Oct. 2023.

The initial proposal for the Red Line commenced in June 2011, gaining momentum with Federal funding commitment in 2014. However, the cancellation of the project by Governor Hogan in 2015 stalled progress until its revival under Governor Wes Moore in June 2023.

This study assesses the potential impact of the Red Line as a rapid transit system on job accessibility in Baltimore. Job accessibility quantifies how easy it is for people to commute to workplaces. Using transit network data from the Maryland Transit Administration Developer Resources and real-time bus data from the Adherence + Reliability + Integrity Evaluation System (Pizzurro & Pizzurro), a multimodal transportation network, combining transit and walking networks, is constructed that generates routes throughout the city via public transit. In this simulation, the Red Line is added to the route options, assuming a vehicle speed of 20 mph and an 8-minute-long headway, initiating the first trip at 7 am each day. Hypothetical transit trips are generated to compute the median travel time between locations. Premised on the assumptions about the Red Line's speed and service times, this simulation enables the calculation of transit times as if the Red Line were in place. Job accessibility is then evaluated based on these transit times before and after the addition of the Red Line using a gravity-based metric commonly used in previous studies (Barri et al., 2021). The results quantify the improvement in job accessibility across Baltimore if the Red Line were to materialize.

The findings from the Baltimore Transit Equity Report by Johns Hopkins University (Baltimore Transit Equity Coalition, 2021) underscore the stark transit inequities prevalent in the city, with low-income people of color constituting the majority of transit users. The Red Line, through its envisioned facilitation of faster and more reliable transit, holds promise in addressing these entrenched inequities, potentially catalyzing improved job accessibility and broader socio-economic mobility for marginalized communities in Baltimore.

Outline of the Report

We begin by highlighting the study's main findings. Next, we describe the service area of the proposed Red Line and collect data around job centers and availability of workers. This is followed by examples of four fictional commuters whose transit times to their places of employment are reduced with the availability of the Red Line. Next, we provide a quantitative assessment of the improved job accessibility. Our findings are summarized in Figures 14 and 15. An analysis which reveals a need for the addition of connecting routes which will have a multiplicative effect on job accessibility is also provided. After a discussion section, we provide technical background on the methodology employed in this study. A final section containing references cited ends the report.

Key Findings

- **Bridging Accessibility Gap**: The Red Line is poised to bridge the gap between residential areas with a high density of mid-to-lower income workers and job centers, potentially enhancing economic mobility and living standards for these individuals in Baltimore.
- **Job Accessibility Improvement**: with a 45-minute threshold time for transit, 20.13% of the population working in mid-to-low income jobs within the service area of the Red Line will see a 50% increase in job accessibility.
- **Enhanced Job Accessibility**: The Red Line significantly amplifies job accessibility, especially in communities on the city's east and west sides, including neighborhoods like Edmondson Village, Clifton Park, Belair-Edison, Greater Rosemont and Mondawmin.

- **Commute Time Reduction**: Simulations for fictional characters Aisha, Baron, Cory, and Darrell living in West and East Baltimore illustrated notable commute time reductions with the Red Line, showcasing savings ranging from 7 to 21 minutes per commute.
- **Job Center Distribution**: Mid-to-lower income Job Centers are primarily located in Downtown and East Baltimore, while West Baltimore hosts a dense population of mid-to-lower income working individuals.
- **Connecting Routes**: Additional transit routes connecting to the Red Line stations could extend its benefits to communities beyond walking distance, enhancing its overall impact on the city's job landscape.

Service Area and Job Centers

Understanding the landscape of job opportunities in Baltimore City, especially in relation to transit equity and job accessibility, is foundational to this report. With a particular interest in mid-to-lower income workers who maintain regular employment but remain in relative poverty, this section uses the Census Bureau's Longitudinal Employer and Housing Dynamics (LEHD) dataset ("LEHD Origin-Destination Employment Statistics (LODES) Dataset Structure"), following a previous study on the impact of light rail on labor markets (Fan, Guthrie, & Levinson, 2012). This annually collected dataset counts individual wages in each of three categories (less than $1250 per month, $1250–$3333 per month and more than $3333 per month) at the census block level. For each census block, the LEHD dataset contains the Residence Area Characteristic (RAC) data, where jobs are totaled by home Census Block, and Workplace Area Characteristic (WAC) data, where jobs are totaled by work Census Block. In our report, we remove all blocks that are neither home blocks (0 jobs as a home census block) nor workplace blocks (0 jobs as a workplace census block). Throughout this report, jobs paying less than $3333 per month—equivalent to less than $39,996 per year and accounting for 39.55 percent of the jobs in Baltimore City—are considered mid-to-lower income jobs and used as indicators of the working population who are more likely to benefit from an affordable transit system. For context, 2021 per-capita income was $34,378 in Baltimore City and $37,638 in the U.S.

In 2020, Baltimore City reported a total of 338,318 jobs, of which 133,825 were categorized as mid-to-lower income positions ("LEHD Origin-Destination Employment Statistics (LODES) Dataset Structure"). When we break this down by the city's 3,415 workplace blocks, we find an average of 99 jobs per block, with 39 of these typically falling into the mid-to-lower income category. A comprehensive summary of job distribution across these workplace blocks can be found in Table 1. In the remainder of this report, we will focus on workplaces located in the service area of the Red Line, as described in the next section.

	All jobs	Mid-to-Lower Income Jobs
Mean	99.07	39.19
Standard deviation	496.48	171.01
Min	1	0
Median	11	0
Max	11741	4246

Table 1: The summary statistics of the number of jobs across the workplace blocks. Note that the standard deviation and maximum are quite large, meaning that there are blocks with many jobs and blocks with very few jobs.

Service Area of the Red Line

The Red Line Project proposes a 14-mile east-west transit corridor connecting key areas of Baltimore, including the Woodlawn area in Baltimore County, communities in West Baltimore, downtown Baltimore, Inner Harbor East, Fells Point, Canton, and the Johns Hopkins Bayview Medical Center. The stations that constitute the Red Line include Centers for Medicare and Medicaid Services, Security Square, Social Security Administration, Edmonston Village, Allendale, Rosemont, West Baltimore MARC, Harlem Park, Poppleton, Howard Street/University Center, Inner Harbor, Harbor East, Fells Point, Canton Crossing, Highlandtown/Greektown, Bayview MARC, Bayview Campus, I-70 Park-and-Ride, and Canton. Figures 1 and 2 visually represent the locations of the proposed Red Line stations and how they integrate with the existing transit network in Baltimore City.

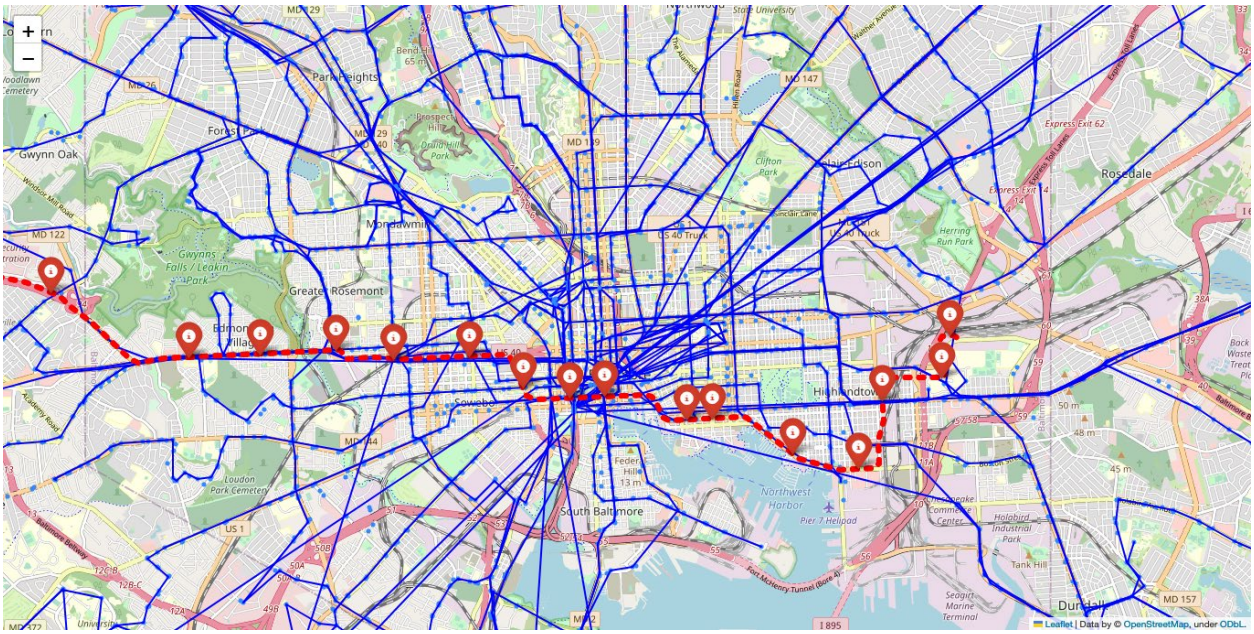

Figure 2. This figure shows the proposed Red Line stations and segments on top of the existing transit network in Baltimore City. The existing transit modes include buses, commuter buses, rails, trains, and subways. Blue dots represent all existing stops, and blue segments represent the approximate routes of these transit services. The red icons and dotted lines represent the proposed Red Line stations and segments.

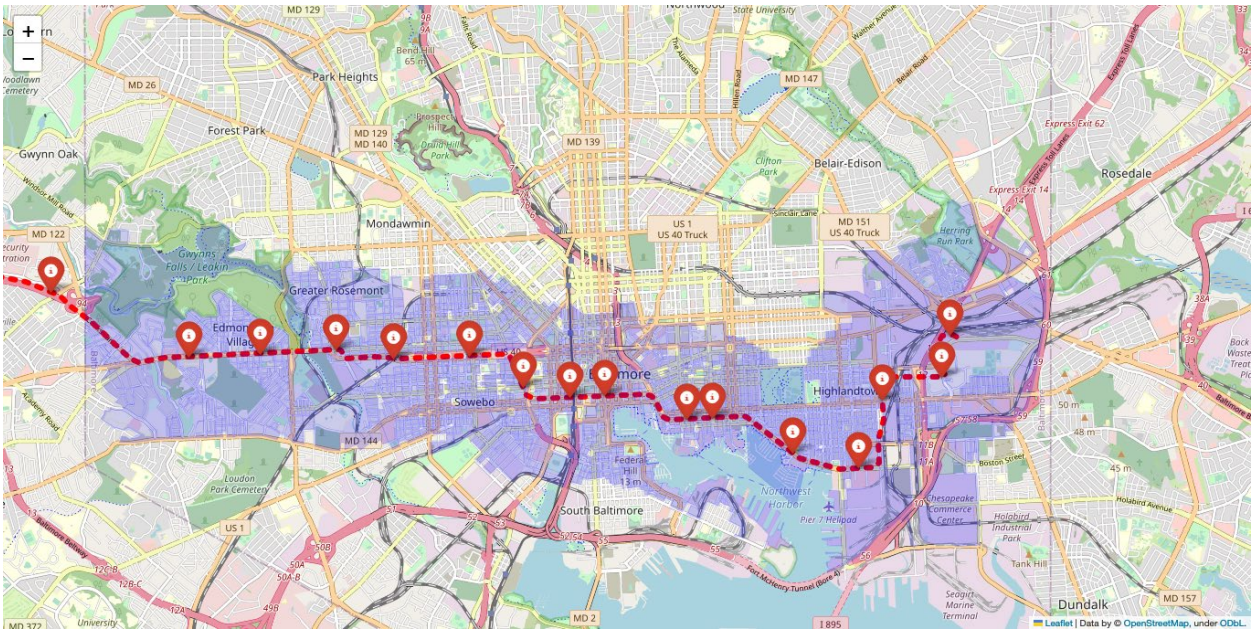

Figure 3. This map highlights the service area of the Red Line in blue. Defined by census blocks within a quarter-mile (402.336 meters or 1,320 feet) of any Red Line station, this representation is fundamental to our analysis. Census blocks without any jobs as a workplace, or any commuters as a home, as categorized by the Longitudinal Employer-Household Dynamics (LEHD) dataset, were excluded from this study.

In this report, the service area of the Red Line is defined as census blocks situated within a quarter-mile (402.336 meters or 1,320 feet) from any designated Red Line station. Figure 3 illustrates this service area within Baltimore City, marked in light blue shades.

Mid-to-Lower Income Job Centers

Figure 4 visualizes the distribution of the locations of mid-to-lower-income jobs in 2020. We identify 12 workplace census blocks, referred as job centers, with an exceptionally high concentration of such jobs. Each of these 12 census blocks contains more than 967.32 jobs, beyond the 99% quantile among all blocks within the service area:

- Blocks 1 and 7: Located in Downtown Baltimore, these blocks encompass high-rise office buildings, indicating the concentration of employment opportunities. Specifically, Wells Fargo Building, Equitable Building, and Suntrust Building in Block 1, and 250 W Pratt Street in Block 7, are significant employment hubs for mid-to-lower-income jobs.
- Block 2: Situated adjacent to the Baltimore City Police Headquarters, District Court of Maryland, Baltimore Police Department - Central District, American Legion Department of MD, and the Baltimore War Memorial, Block 2 serves as a hub for civic, legal, and governmental functions. The presence of these institutions suggests a concentration of administrative, clerical, security, and support roles that often cater to mid-to-lower income job opportunities. Furthermore, such establishments typically have numerous ancillary services and roles that are vital to their operations, thereby creating a diverse range of employment options within this block.
- Blocks 3, 8, 9, and 10: These blocks are either adjacent to or encompass major healthcare centers. For instance, Mercy Medical Center in Block 3, Johns Hopkins Hospital in Blocks 8 and 10, and University of Maryland Hospital in Block 9. These institutions serve as major employers for the city, with many of the jobs fitting the mid-to-lower-income category.

- Blocks 4, 5, 6, and 12: These blocks predominantly cater to logistics and warehousing services, which are vital for a city's distribution infrastructure. Blocks 4, 5, and 6 house an Amazon fulfillment center, a hub for sorting, packing, and shipping products, often requiring a large workforce for various roles. Block 12 is home to the Belts Business Center, offering mini-storage, truck rental, and warehouse storage facilities, as well as the Shipco Transport, a cargo and freight services business. The nature of these businesses, particularly in warehousing and logistics, often demands roles that fall into the mid-to-lower-income bracket, making these blocks significant employment centers for such job categories.
- Block 11: This block contains the Philadelphia Power Plant, a significant employment source in the energy sector for the city.

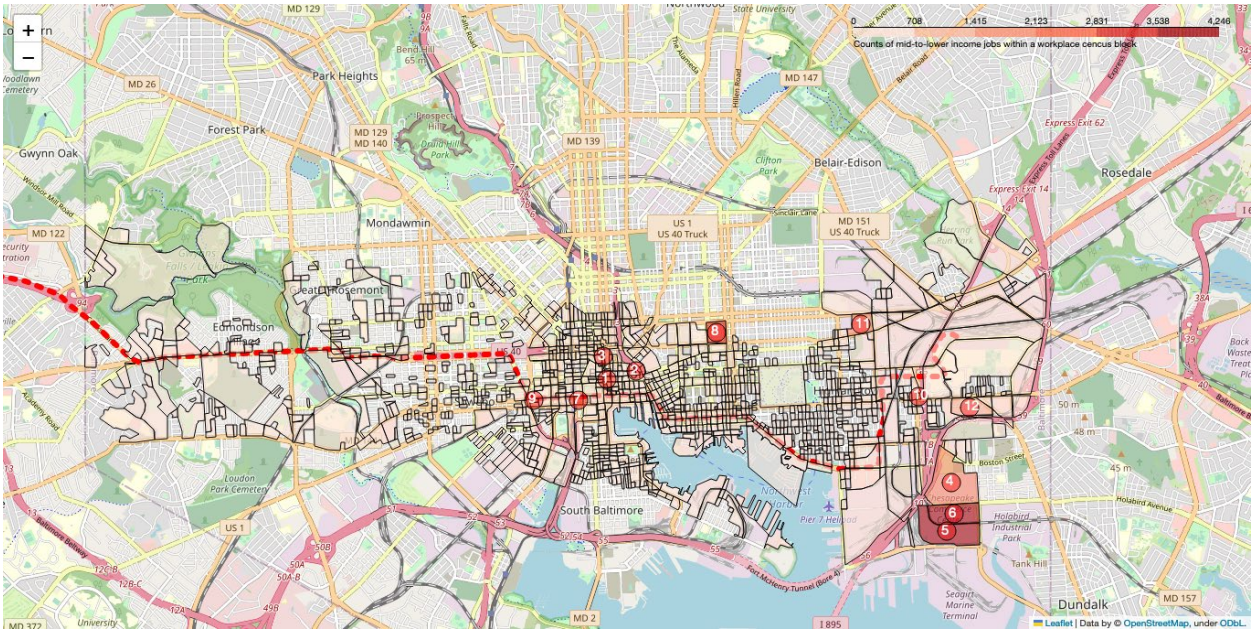

Figure 4. Distribution of Mid-to-Lower-Income Jobs (2020). A heatmap of the number of mid-to-lower-income jobs in each workplace census block. Highlighted are the top 12 workplace census blocks with job numbers surpassing the 99% quantile (> 967.32 jobs).

Mid-to-Lower Income Working Population

Figure 5 examines the distribution of the density of workers in mid-to-lower-income jobs across various census blocks in Baltimore. The density is computed by dividing the number of mid-to-lower-income workers by the total number of workers in each block. We identify several communities with higher density of mid-to-lower-income workers:

- Gwynns Falls/Leakin Park Area: Situated on the western edge of Baltimore, the area around Gwynns Falls/Leakin Park has many mid-to-lower-income workers. This region is mainly residential with expansive parklands, a mix of single-family homes, and some apartment buildings. Historically, the area witnessed demographic shifts in the late 20th century, with a growing African American population replacing a once predominantly white community.
- Greater Rosemont: Positioned slightly to the northeast of Gwynns Falls, Greater Rosemont holds a notable number of mid-to-lower-income workers. The neighborhood consists mostly of residential properties, including rowhouses. Throughout the years, Rosemont has seen racial dynamics evolve, with an increasing African American population since the mid-20th century.

- Mondawmin: Located north of Greater Rosemont, Mondawmin showcases a significant density of mid-to-lower-income workers. The region is primarily residential with a blend of rowhouses and apartment complexes. The racial history here is characterized by a shift during the mid-20th century, moving from a white majority to a predominantly African American community.
- Druid Hill Park Area: Nestled to the northeast of Mondawmin, this area is home to many mid-to-lower-income workers. It is a mix of residential zones surrounding the large Druid Hill Park and has an assortment of housing types. Racially, the region transitioned in the latter half of the 20th century, becoming largely African American.
- Central Baltimore (US 1 and US 40 Truck routes): Found in the heart of Baltimore, this central region has a pronounced density of mid-to-lower-income workers. This area combines residential living with commercial districts, offering a mix of housing and businesses. Historically, it has witnessed several racial transitions, particularly in the latter half of the 20th century, evolving into a diverse urban center.
- Baltimore Cemetery Area: Located in the northeast part of the city, the vicinity of Baltimore Cemetery has a good number of mid-to-lower-income workers. The area is mainly residential, dominated by rowhouses. Its racial history is marked by shifts in the late 20th century, where the African American community became more prevalent.
- Belair-Edison: Positioned further east of Baltimore Cemetery, Belair-Edison has a clear presence of mid-to-lower-income workers. This neighborhood is largely residential, known for its rowhouses and a few commercial spots. Historically, the area transitioned from a primarily white community to a mainly African American one during the late 20th century.
- Baltimore Harbor (MD 2 and I-895 intersection): Situated in the southeast of Baltimore, this region near the harbor sees a noticeable number of mid-to-lower-income workers. It's a blend of residential and commercial spaces, with many waterfront properties. The area's racial history is rich and diverse, witnessing demographic shifts throughout the 20th century, with a notable increase in the African American community.

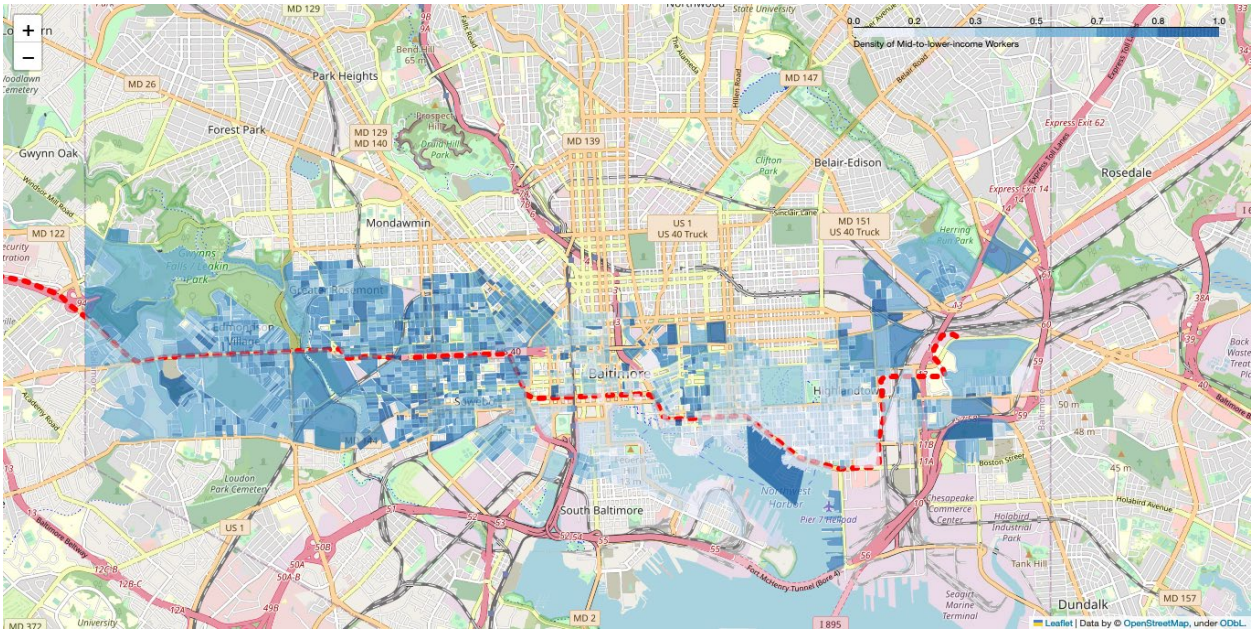

Figure 5. Distribution of the density of workers in mid-to-lower-income jobs across various census blocks within the service area. Areas with darker shading represent a higher percentage of workers in mid-to-lower-income jobs.

Case Studies

We have identified that a significant portion of mid-to-lower income job centers are concentrated in the central and eastern parts of Baltimore. In contrast, communities in West Baltimore have a dense population of mid-to-lower income workers. Many of these residents are likely reliant on public transit out of necessity. This underscores the potential significance of the Red Line, facilitating east-west commutes. We present four case studies showcasing how the Red Line can notably reduce commute times for these workers. In these four case studies, we use different colors for different transit modes: blue for bus, green for walking, and red for the Red Line.

Aisha, from Greater Rosemont to University of Maryland Hospital: Figures 6 and 7 outline a simulated morning commute for Aisha, a fictional character. She lives at 2916 Riggs Ave (Red marker, census block 245101607002002, located in the Greater Rosemont area) and works at the University of Maryland Hospital (Green marker, census block 245100402001036). The detailed routes are shown in Table 2. On April 10th, 2023, her commute using existing transit options would take about 45 minutes. However, with the Red Line in operation, her commute time could be reduced to approximately 35 minutes. The data clearly shows that the Red Line would save Aisha approximately 10 minutes on her daily commute. This reduced travel time enhances not just Aisha's work-life balance, but also stands as an example of the broader benefits to community members, offering them easier access to employment opportunities in different parts of the city.

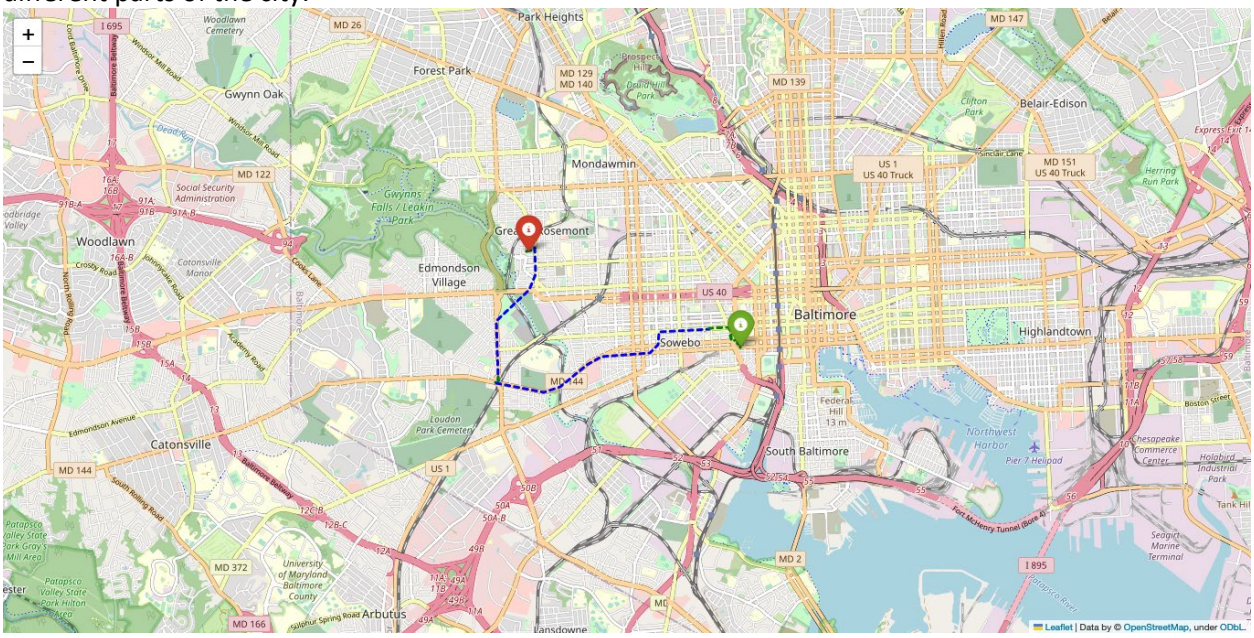

Figure 6: Aisha's Conventional Route: Aisha departs from her home at 08:09 am. She takes Bus 29 for 8 minutes, followed by a short walk and a 12-minute ride on the CityLink Purple bus. She then walks for 13 minutes to arrive at her workplace by 08:54 am. Total Travel Time: 45 minutes.

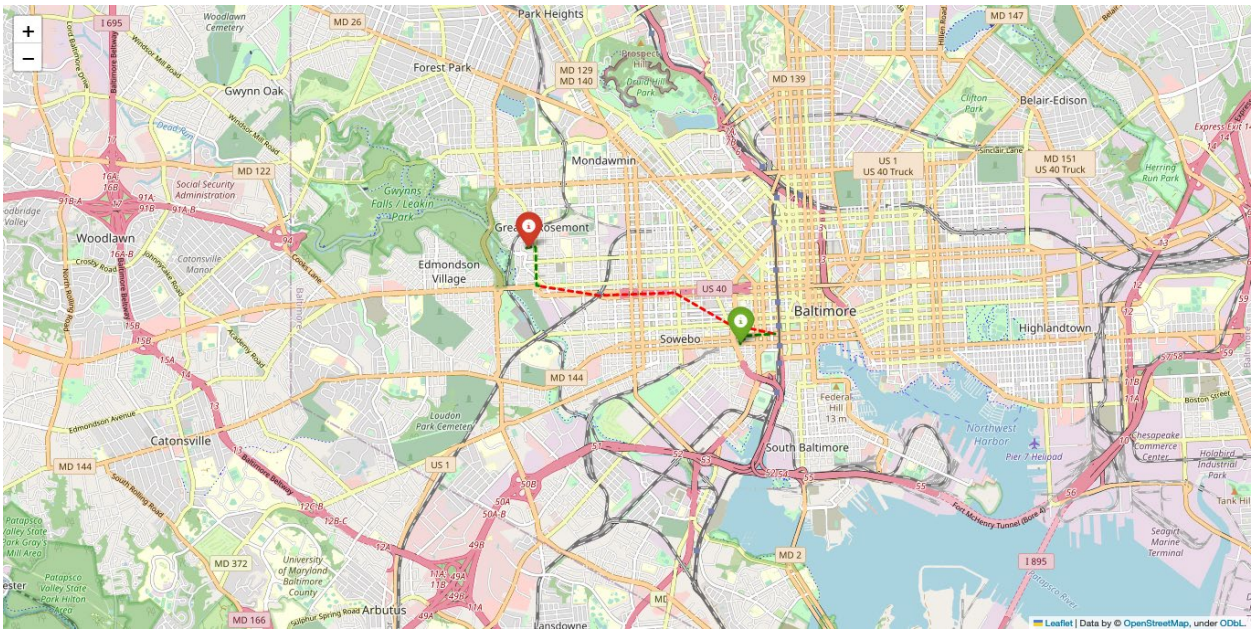

Figure 7: Aisha starts her commute at 08:08 am and walks for 14 minutes to the Red Line tram station. At 08:23 am, she boards the Red Line tram, traveling for roughly 8 minutes. After leaving the tram, Aisha walks for another 11 minutes to reach her final destination by 08:43 am. Total Travel Time: 35 minutes.

Comparative Commute Scenarios for Aisha: With and Without the Red Line		
Steps	**Without Red Line**	**With Red Line**
Leave Starting Point	08:09 am	08:08 am
First Transit	Walk 3 minutes	Walk 14 minutes
Board	Route 29 at 08:12 am	Red Line at 08:23 am
Ride Duration	8 minutes	8 minutes
Transfer	Walk 2 minutes	-
Next Ride Duration	CityLink PURPLE for 12 minutes	-
Arrival	Walk 14 minutes to destination	Walk 11 minutes to destination
Total Travel Time	45 minutes	35 minutes

Table 2: Comparative analysis of a simulated morning commute for Aisha, with and without the proposed Red Line.

Baron, from Franklintown to Downtown Baltimore: Figures 8 and 9 outline a simulated morning commute for a fictional character named Baron. He lives at 5048 Carmine Ave (census block 245102803011001, located in Franklintown) and works at West Pratt Street (census block 245100401002008). The detailed routes are shown in Table 3. On April 10th, 2023, his commute using existing transit options would take about 64 minutes. However, with the Red Line in operation, his commute time could be reduced to approximately 43 minutes. With a shorter commute time, Baron might be more open to attending events, courses, or other activities after work, which he might have previously avoided due to a longer commute.

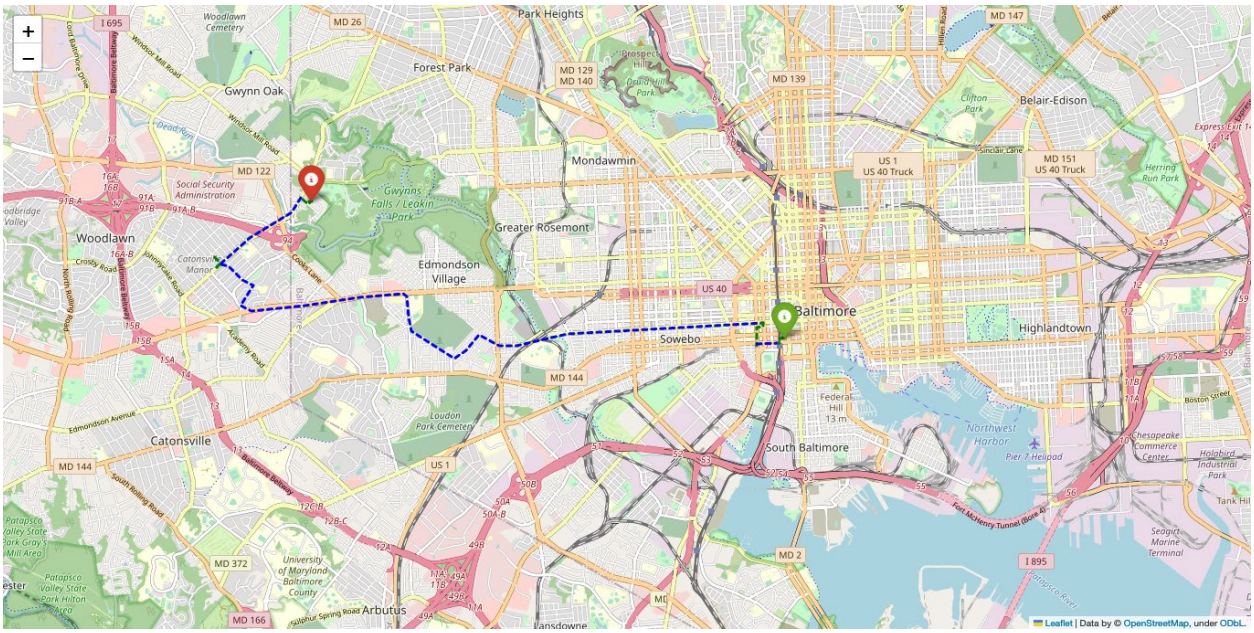

Figure 8: Baron's Conventional Route: Baron departs from his starting point at 08:00 am. He begins with a walk of about 4 minutes, then boards Bus 34 for a short 2-minute ride. Following this, he walks for approximately 1 minute before taking a long 37-minute bus ride on Bus 78. Once he arrives, he walks for around 8 minutes, takes a brief 1-minute bus ride on Bus 76, and concludes his trip with a 2-minute walk, arriving at his destination by 09:04 am. Total Travel Time: 64 minutes.

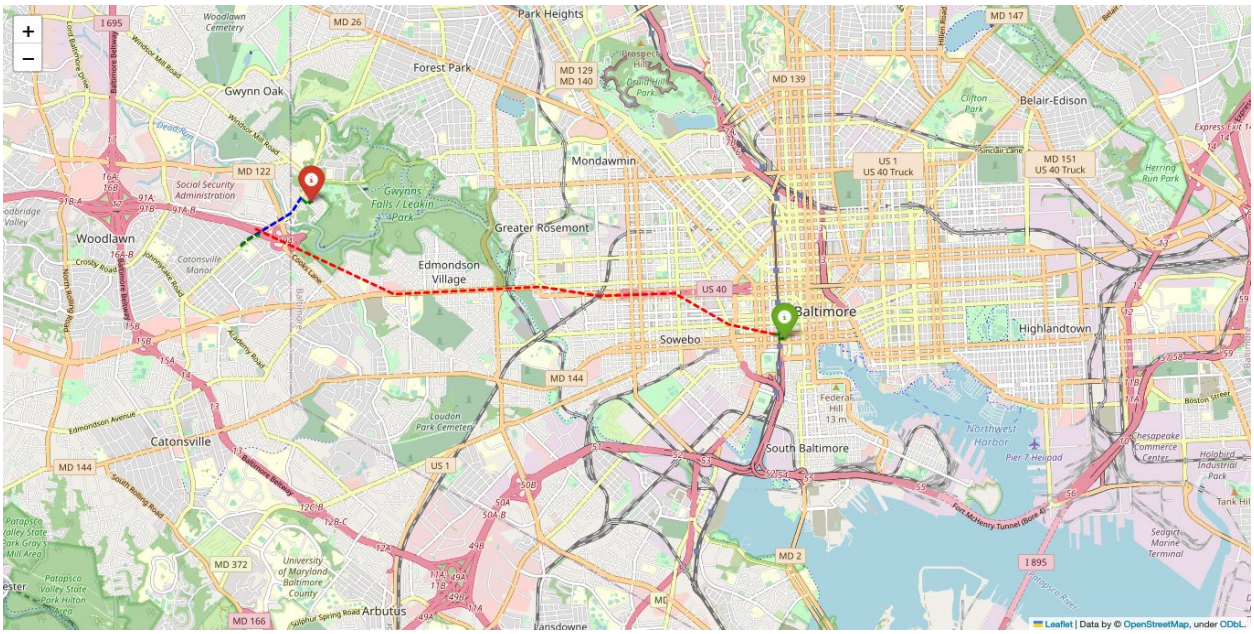

Figure 9: Baron's Route with the Red Line: Starting at 08:00 am, Baron starts with a 4-minute walk before boarding Bus 34 for a 1-minute journey. He then walks for about 6 minutes to get to a Red Line station and takes the Red Line tram for 19 minutes. Baron concludes his journey with a 3-minute walk to reach his destination, arriving by 08:49 am. Total Travel Time: 43 minutes.

Comparative Commute Scenarios for Baron: With and Without the Red Line		
Steps	**Without Red Line**	**With Red Line**
Leave Starting Point	08:00 am	08:00 am
First Transit	Walk 4 minutes	Walk 4 minutes

Board	Bus 34 at 08:06 am	Bus 34 at 08:06 am
Ride Duration	2 minutes	1 minute
Walk/Wait Time	Walk 1 minute	Walk 6 minutes to station
Second Transit	Board Bus 78 at 08:13 am	Board Red Line at 08:20 am
Ride Duration	37 minutes	19 minutes
Walk/Transit Time	Walk 8 minutes, then board Bus 76 for 1 minute	Walk 3 minutes to destination
Final Transit/Walk	Walk 2 minutes to destination	-
Total Travel Time	64 minutes	43 minutes

Table 3: Comparative analysis of a simulated morning commute for Baron, with and without the proposed Red Line.

Cory, from Canton to Downtown Baltimore: Figures 10 and 11 outline a simulated morning commute for a fictional character named Cory. She lives at 220 S Haven St (census block 245102608001020, located in the Canton area) and works at 250 W Pratt Street (census block 245100401002008). The detailed routes are shown in Table 3. On April 10th, 2023, her commute using existing transit options would take about 36 minutes. However, with the Red Line in operation, her commute time could be reduced to approximately 29 minutes. Those extra 7 minutes saved daily can be used more productively. Over a week, this amounts to over half an hour, and over a month, it's over 2 hours. This time can be spent spending time with her family, learning a new skill, or even pursuing a hobby.

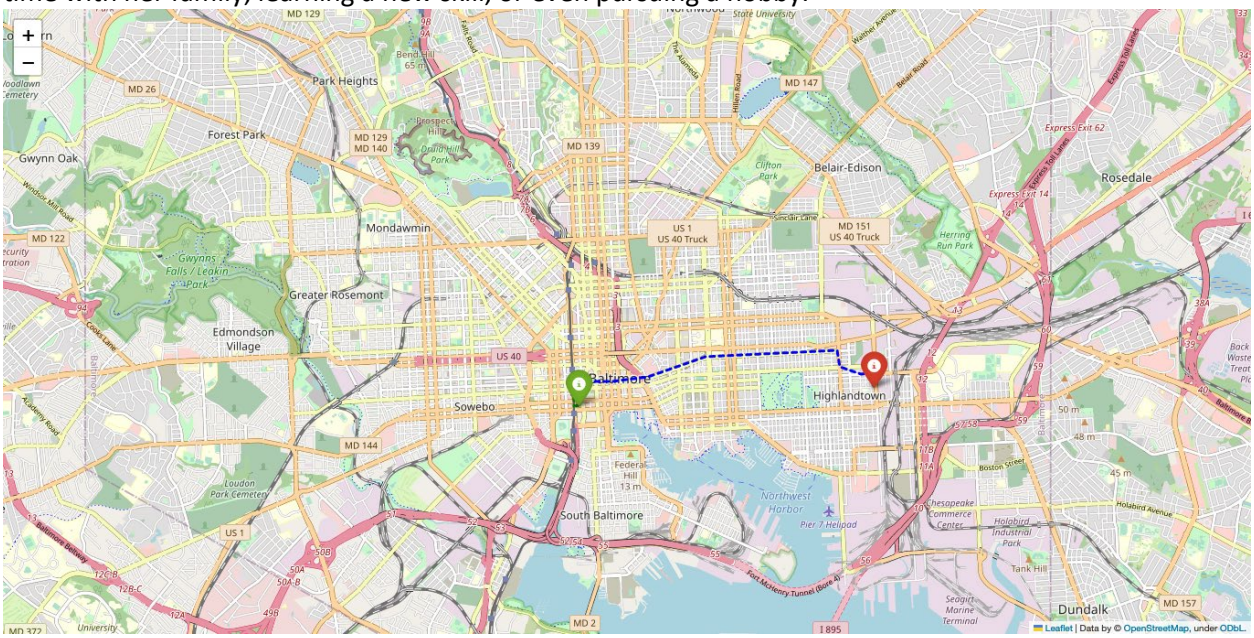

Figure 10: Cory's Conventional Route: Cory starts her commute at 08:03 am by walking for about 5 minutes. At 08:08 am, she boards the CityLink ORANGE bus and travels for approximately 21 minutes. Once she arrives, she walks for around 9 minutes to reach her final destination, with her journey concluding by 08:39 am. Total Travel Time: 36 minutes.

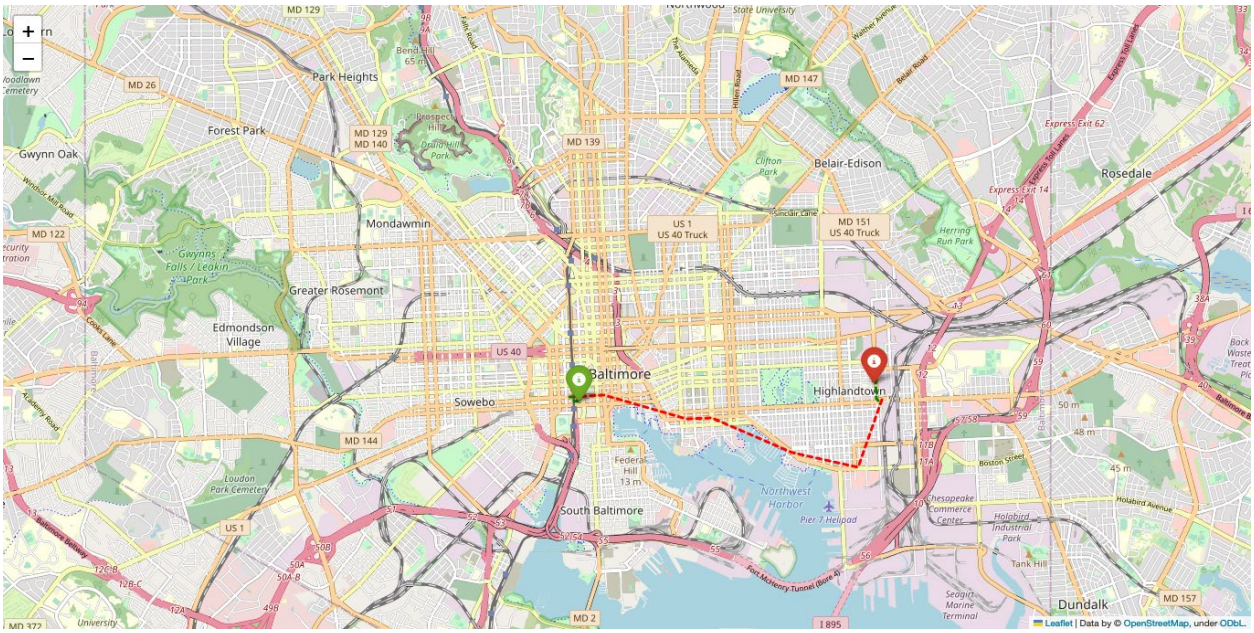

Figure 11: Cory's Route with the Red Line: Cory leaves her starting point at 08:04 am and takes a 10-minute walk to reach the Red Line station. She boards the Red Line at 08:16 am and travels for 15 minutes. After her light rail journey, Cory walks for another 3 minutes to arrive at her destination, reaching it by 08:33 am. Total Travel Time: 29 minutes.

Comparative Commute Scenarios for Cory: With and Without the Red Line		
Steps	**Without Red Line**	**With Red Line**
Leave Starting Point	08:03 am	08:04 am
First Transit	Walk 5 minutes	Walk 10 minutes
Board	CityLink ORANGE at 08:08 am	Red Line at 08:16 am
Ride Duration	21 minutes	15 minutes
Walk/Transit Time	Walk 9 minutes to destination	Walk 3 minutes to destination
Total Travel Time	36 minutes	29 minutes

Table 4: Comparative analysis of a simulated morning commute for Cory, with and without the proposed Red Line.

Darrell, from Southwestern Baltimore to Logistics Hub in East Baltimore: Figures 12 and 13 outline a simulated morning commute for a fictional character named Darrell. He lives at 3600 W Franklin St (census block 245102007015006, situated in the Southwestern Baltimore neighborhood) and works at 608 Folcroft St, Belts Logistic (census block 245102605013028). The detailed routes are shown in Table 3. On April 10th, 2023, his commute using existing transit options would take about 66 minutes. However, with the Red Line in operation, his commute time could be reduced to approximately 55 minutes. A shorter commute, especially with the use of public transit like the Red Line, can mean a smaller carbon footprint. Darrell's choice to utilize efficient transport modes contributes to a reduction in greenhouse gas emissions. Even a savings of 10-15 minutes each day can accumulate to hours over a week, translating to a significant positive impact on his quality of life.

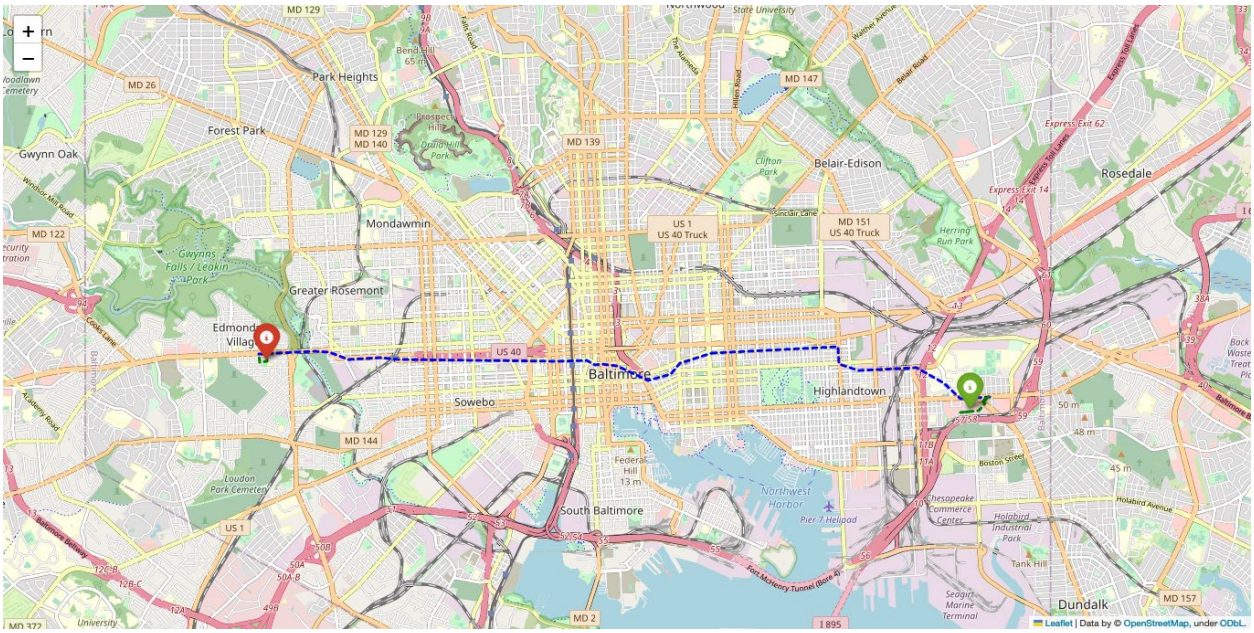

Figure 12: Darrell's Conventional Route: Darrell begins his commute at 08:07 am, walking for approximately 5 minutes. At 08:13 am, he boards the CityLink BLUE bus, traveling for about 29 minutes. At 08:43 am, he switches to the CityLink ORANGE bus, continuing his journey for another 17 minutes. Once off the bus, Darrell walks for about 12 minutes to reach his final destination by 09:13 am. Total Travel Time: 66 minutes.

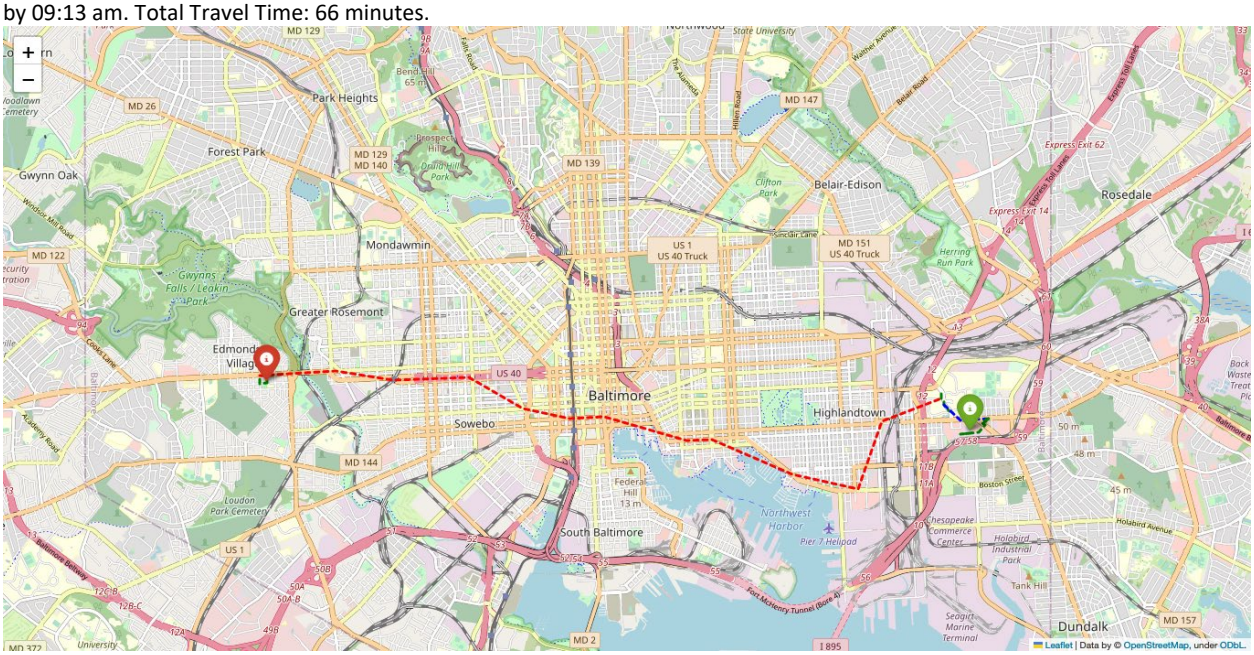

Figure 13: Darrell's Route with the Red Line: Darrell starts at 08:07 am and takes a 5-minute walk to the Red Line tram station. At 08:13 am, he boards the Red Line tram, traveling for roughly 28 minutes. At 08:41 am, he walks for a short 2 minutes and then boards the CityLink ORANGE bus at 08:44 am, which takes him another 4 minutes. Finally, Darrell walks for 12 minutes, reaching his destination by 09:02 am. Total Travel Time: 55 minutes.

Comparative Commute Scenarios for Darrell: With and Without the Red Line		
Steps	**Without Red Line**	**With Red Line**
Leave Starting Point	08:07 am	08:07 am
First Transit	Walk 5 minutes	Walk 5 minutes

Board	CityLink BLUE at 08:13 am	Red Line at 08:13 am
Ride Duration	29 minutes	28 minutes
Transfer	Switch to CityLink ORANGE	Walk 2 minutes
Next Ride Duration	18 minutes	CityLink ORANGE for 4 minutes
Arrival/Walk to Destination	Walk 12 minutes to destination	Walk 12 minutes to destination
Total Travel Time	66 minutes	55 minutes

Table 5: Comparative analysis of a simulated morning commute for Baron, with and without the proposed Red Line.

Job Accessibility

Next, we analyze the benefit of the Red Line at the macroscale and assess the overall increase in job accessibility for communities throughout the service area.

Imagine you live in a big city and you're looking for a job. The city is filled with various job opportunities, but not all of them are easy to reach from where you live. Some jobs might be just a short walk or a quick bus ride away, while others might require a long, costly commute. Gravity-based job accessibility is a quantitative measure of how easy it is to reach these workplaces from your home.

This way of quantifying access to jobs uses the idea that jobs closer to you are more attractive compared to the ones far away, because, naturally, people prefer shorter commutes. It's like a magnet where the job opportunities are pulling you towards them, but the pull gets weaker the further away you are. For the exact definition of job accessibility used in this report, we refer the reader to the Methods and Data section.

Threshold Time

Imagine you are job hunting in a city. You would prefer a job close to home to avoid long commutes, but might travel longer for a great job. The "threshold time" is your maximum acceptable commute time. Beyond this, no job is worth the travel.

In gravity-based job accessibility models, this threshold time helps measure how many jobs are available within this acceptable travel time from different areas in the city. It acknowledges that closer jobs are more appealing, up to this cutoff time. In this report, we choose 30 and 45 minutes as threshold times.

Connections to and Distinctions from Job Opportunities

Job accessibility and job opportunities are distinct yet interrelated concepts crucial in urban and regional planning. Job accessibility pertains to the ease with which individuals can reach job venues from their homes, taking into account travel time, distance, and transportation availability. On the other hand, job opportunities refer to the availability of job positions within a specific area or region.

There is a potential direct relationship between the two; an increase in job opportunities might enhance job accessibility, especially if these jobs are distributed across various areas, reducing travel distances for many residents. Conversely, improved job accessibility might attract more employers to a region, thus potentially increasing job opportunities. This is because regions with better accessibility might appeal more to employers due to the larger pool of potential employees who can commute easily.

However, these concepts can also operate independently. Job opportunities can rise without a corresponding increase in job accessibility, like when new jobs are clustered in distant or poorly connected areas making it hard for individuals to access them. Likewise, job accessibility can improve without a rise

in job opportunities, like through enhanced public transportation or infrastructure facilitating easier access to existing job centers.

From an urban planning standpoint, planners often strive to boost both job accessibility and job opportunities as part of a comprehensive strategy to improve a region's economic and social wellness. By addressing transportation and zoning challenges, they can help ensure residents have easy access to a variety of job opportunities. While there is a connection between job accessibility and job opportunities, an increment in one does not automatically lead to an increment in the other. Each can influence the other, but they are also affected by other factors like urban planning policies, economic conditions, and transportation infrastructure.

Improved Job Accessibility to Mid-to-Lower Income Jobs

The results in this section show that the Red Line's addition will bring about meaningful enhancements in job accessibility for Baltimore City. Communities positioned on the peripheries of the urban core, especially on the east and west sides, will benefit most.

Figures 14 and 15 provide a comprehensive visualization of the positive impact of the Red Line on job accessibility across various neighborhoods in Baltimore. Both figures present heatmaps which showcase the percentage increase in median gravity-based job accessibility across the 104 weekdays considered. The differing thresholds—30 minutes in Figure 14 and 45 minutes in Figure 15—offer distinct perspectives on how transportation infrastructure can affect job accessibility for local communities. For better visual representation, any improvement ratio exceeding 50% is capped. That is, for blocks with the darkest shade of red, the increase in job accessibility in that block exceeds 50%.

Figure 14 focuses on a threshold of 30 minutes for a maximum commute time. The heatmap shows how each block's improvement is calibrated relative to its accessibility before the Red Line's introduction. The simulation indicates that among the 837 home blocks in the service area, **204 home blocks will experience a rise of at least 50% in job accessibility**, and 310 blocks will see an increase of at least 25%. There is heightened job accessibility for neighborhoods located predominantly to the west and southeast of the city center. Notably, Edmondson Village and sections of South Baltimore closer to the harbor experience a remarkable surge in accessibility. Areas around Greater Rosemont and Mondawmin further validate this observation.

Figure 15 increases the threshold to a 45 minute maximum commute time. Here, **288 home blocks within the service area will experience a 50% increase in job accessibility**. In terms of the population working in mid-to-low income jobs within the service area of the Red Line, 20.13% of which will see a 50% increase in job accessibility. Meanwhile, 521 blocks will register at least a 25% surge. This data underscores the Red Line's role in amplifying job accessibility notably for communities situated at the eastern and western extremities of Baltimore City. Compared against Figure 14, with a 45-minute threshold, Figure 15 shows that the benefits of the Red Line will stretch to the far east and west of Baltimore City. This can be observed in neighborhoods surrounding Clifton Park, Belair-Edison, and Herring Run Park on the eastern front, while Gwynns Falls Park and Mondawmin remain as focal points on the west.

In summary, the Red Line plays a crucial role in bridging the gap between residential areas with a high density of mid-to-lower income workers and the job centers distributed across the city. By enhancing job accessibility, the Red Line potentially contributes to improving the economic mobility and living standards of mid-to-lower income individuals in Baltimore.

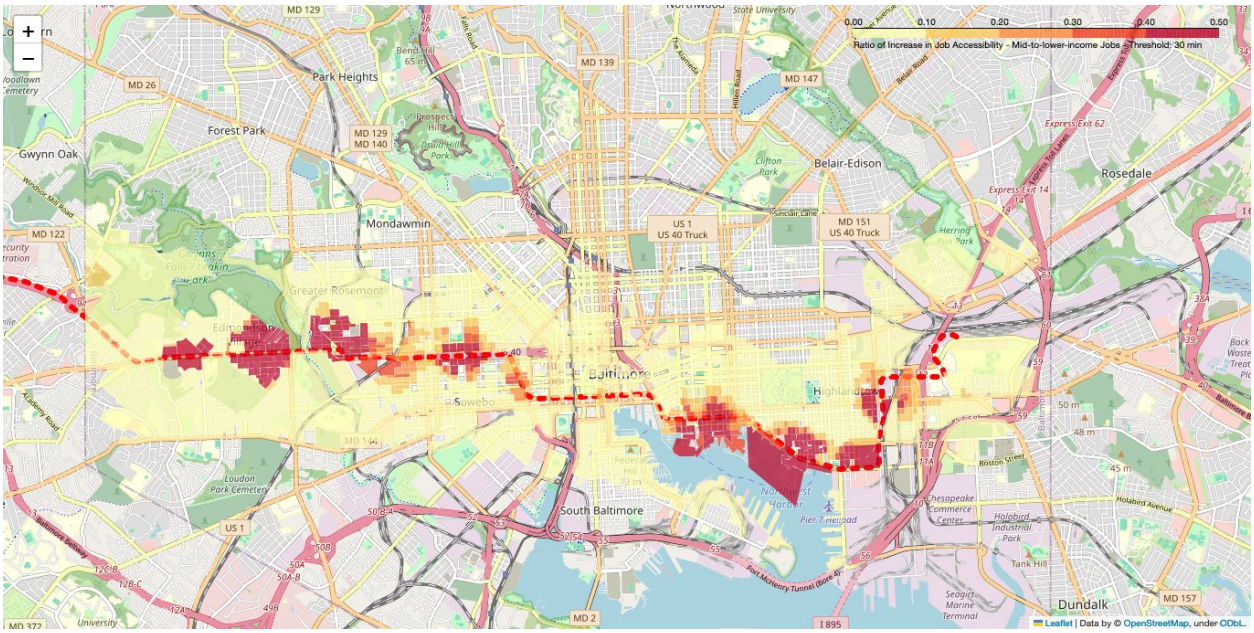

Figure 14: Percentage increase heatmap in median gravity-based job accessibility across 104 weekdays. This index incorporates jobs with a threshold of 30 minutes. Each block's augmentation is measured against its pre-Red Line accessibility. The darkest shade of red indicates that the increase in job accessibility in that block exceeds 50%.

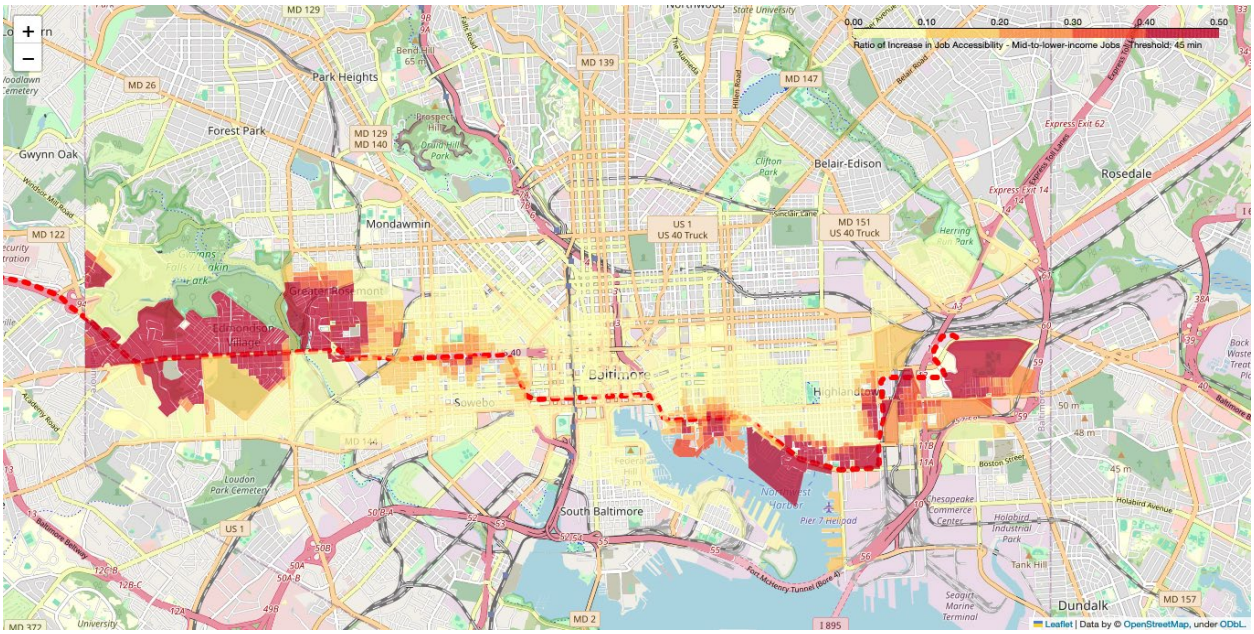

Figure 15: Percentage increase heatmap in median gravity-based job accessibility across 104 weekdays. This index incorporates jobs with a threshold of 45 minutes. Each block's augmentation is measured against its pre-Red Line accessibility. The darkest shade of red indicates that the increase in job accessibility in that block exceeds 50%.

A More Robust Transit System for Baltimore

Connecting Routes

Figure 15 reveals significant increases in job accessibility via transit in the Greater Rosemont area. We provide a closer examination of this area in Figures 16, 17, and 18, where Red Line segments and existing transit routes overlay the increase in job accessibility visualization. In particular, Figure 16 shows the Edmondson Ave & Longwood St and the Edmondson Ave & Poplar Grove St bus stops located adjacent to the Rosemont station. Meanwhile, Figure 17 illustrates that several bus stations surround the West Baltimore MARC station. Importantly, these bus routes not only link the Rosemont and West Baltimore MARC stations to the greater Rosemont areas but, when connected with the Red Line, also serve as vital links to the east side, center, and west side of the city. This extended connectivity opens up diverse job markets and educational opportunities for communities that are beyond a walking distance to these two Red Line stations. This robust connectivity also explains the possibility of saved transit time for Aisha in our case study earlier.

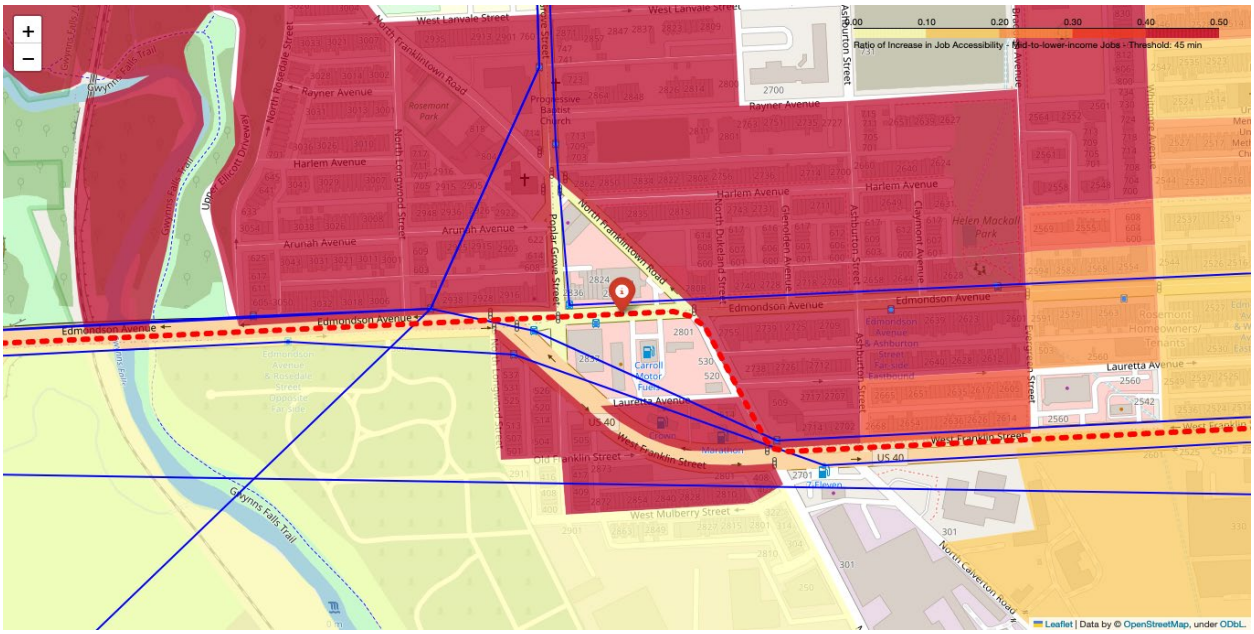

Figure 16: Detailed View of the Bus Stop Proximity to the Rosemont Red Line Station

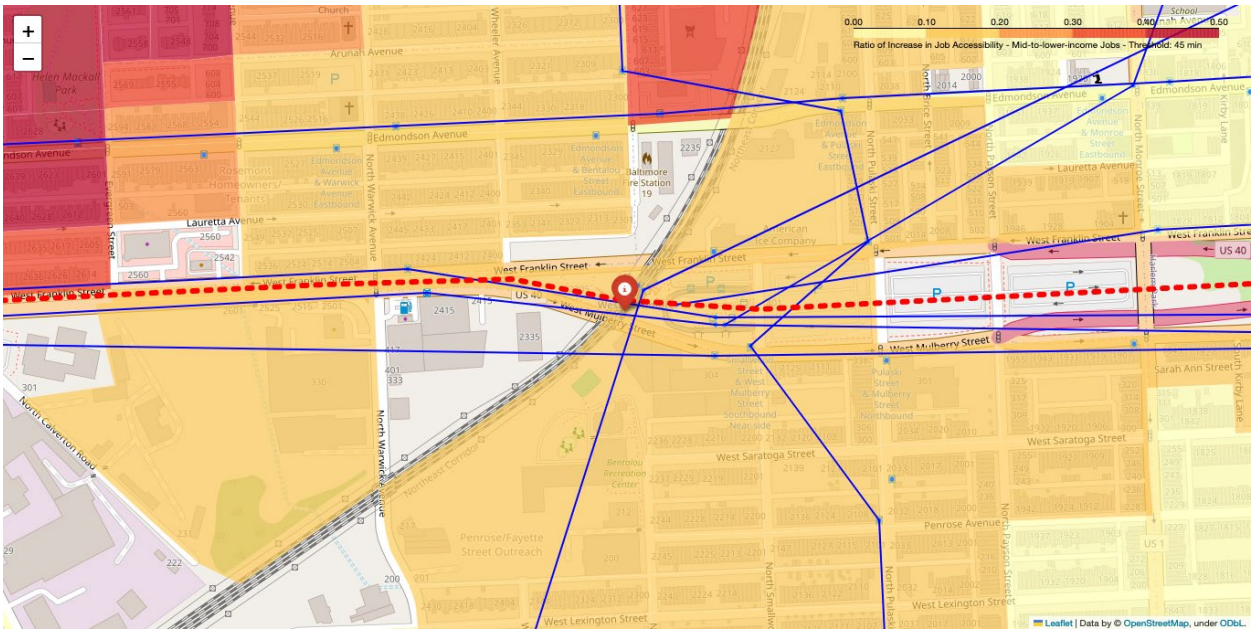

Figure 17: Detailed View of the Bus Stop Proximity to the West Baltimore MARC Station

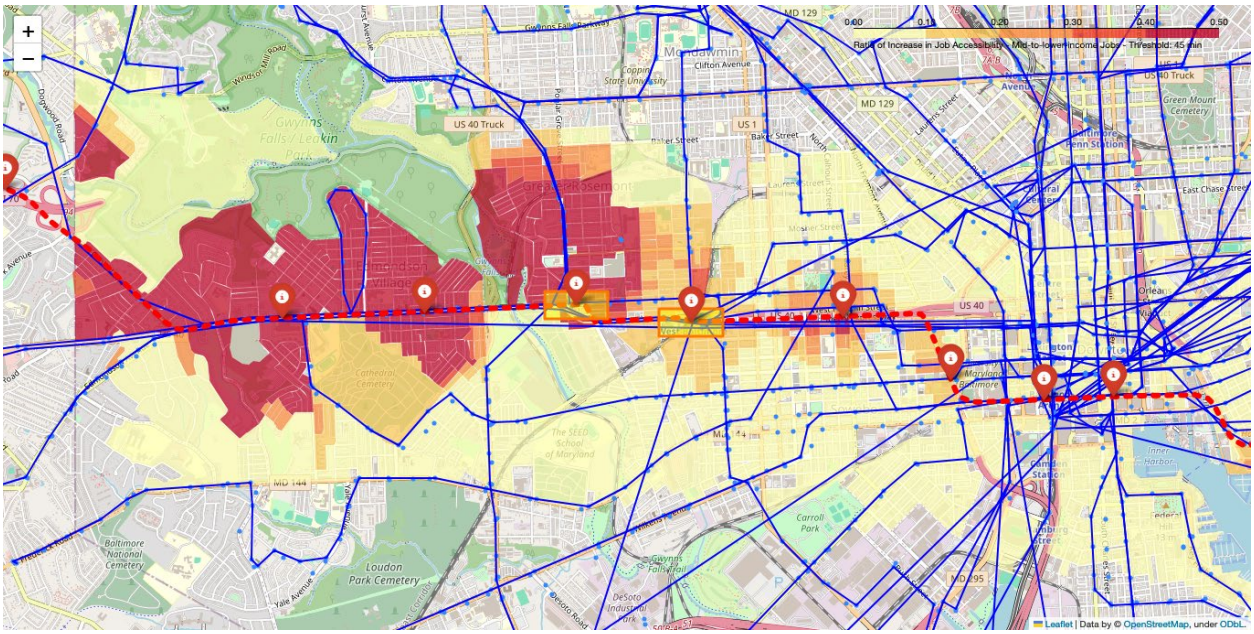

Figure 18: The Network of Bus Routes Connecting the Rosemont Station and the West Baltimore MARC Station.

Inaccessible Job Centers

In contrast to the well-connected Greater Rosemont area, the Chesapeake Commerce Center stands as an example of inaccessibility for Red Line riders. Figure 19 offers a closer look at this center, particularly highlighting the significant Amazon fulfillment center housed within. Overlaying the Red Line segments and existing transit routes on this center, as shown in Figure 7, reveals the clear gap in direct connectivity between the Red Line stations and this job center. From Canton Crossing to Chesapeake Commerce Center, the walking duration is approximately 35.4 minutes. On the other hand, Highlandtown/Greektown to the Commerce Center requires a walk of about 44.39 minutes. For many commuters, particularly those

who embark on this journey daily, these durations, especially under unfavorable weather conditions, might prove infeasible. This evident disconnect accentuates the need for enhanced transit connectivity.

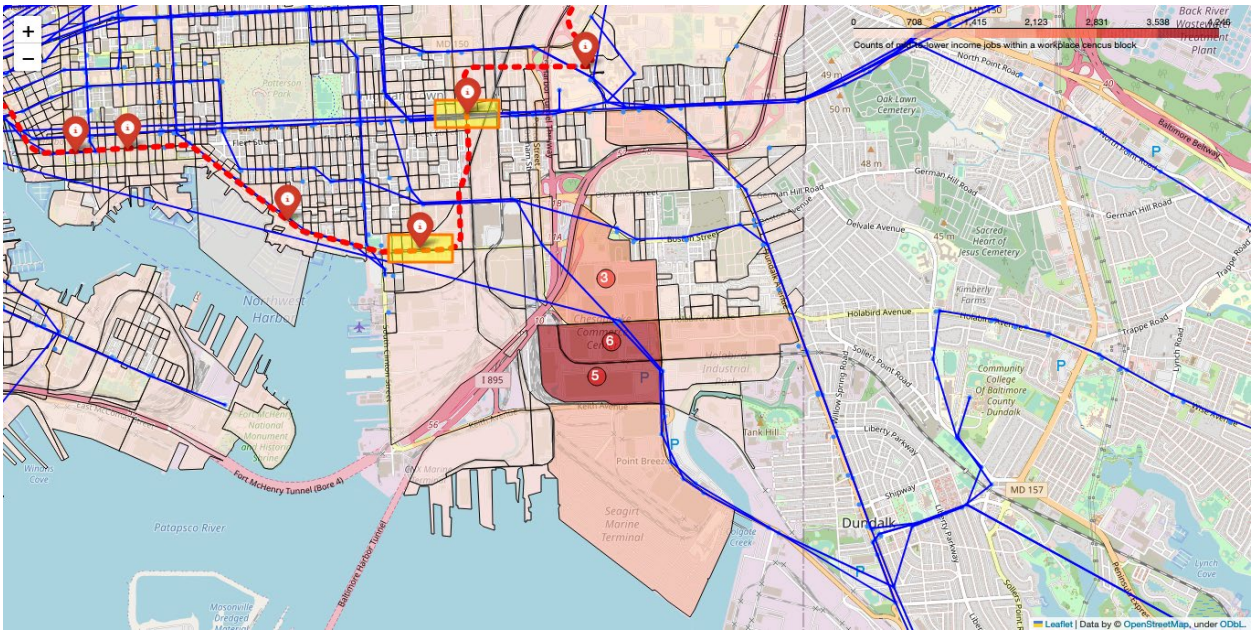

Figure 19. The Chesapeake Commerce Center region in detail. Canton Crossing and Highlandtown/Greektown are the closest red line stations. However, there is a lack of transit routes offering direct links from these stations to the Chesapeake Commerce Center, denoted by points 3, 5, and 6 in the visual.

Discussion and Limitations

The necessity of public transit for Baltimore is underlined by a combination of socio-economic and geographic factors, magnifying its importance as a lifeline for daily commuting and access to essential services. Baltimore has a notably high proportion of commuters relying on public transportation (18%), vastly surpassing the national average of 5.1% (Titus). Particularly, public transportation in Baltimore is a primary mode of commuting for lower-income workers, contrasting the national trend where median-income workers predominantly utilize it. Moreover, during the COVID-19 pandemic, it was estimated that 40% of Baltimore's essential workers relied on public transit for commuting across the city (Sweeney). This reliance is further demonstrated by the extended average commuting time in Baltimore (30 minutes) compared to the national average (26 minutes), underscoring a critical need for a robust, efficient, and equitable transit system. Furthermore, with a higher percentage of workers in Baltimore choosing to walk to work than the national average, it is evident that affordable and accessible transit options are indispensable for the socio-economic mobility and overall well-being of communities in Baltimore (Pinto). The transit system's role is not merely confined to facilitating employment access but extends to impacting the broader quality of life, environmental health, and community connectivity, which are essential for fostering a thriving and equitable urban environment.

Communities Most Benefited

The transformative impact of the Red Line is especially pronounced in specific Baltimore communities, as revealed by our analysis. Neighborhoods like Greater Rosemont, Edmondson Village and sections of South Baltimore see marked improvements in job accessibility within a 30 minute commute. Extending the threshold to 45 minutes amplifies the Red Line's benefits to communities such as Clifton Park, Belair-

Edison, and Herring Run Park. These areas have historically faced challenges in job accessibility, and the Red Line promises to act as an equalizing force. The ripple effects of such increased accessibility can extend beyond just employment opportunities; it can spur local business growth, increase property values, and overall, enhance the quality of life in these communities. Therefore, policy initiatives should particularly focus on these areas to maximize the social and economic impact of the Red Line.

In 2023, a Chicago-based developer received approval to amend architectural and construction restrictions, signaling the beginning of redevelopment efforts for the once-thriving Edmondson Village shopping center (Ilardi). The HUB West Baltimore Community Development Corporation and the revitalized Edmondson Community Organization are also collaborating to bring rapid, equitable, transformational revitalization to neighborhoods around the West Baltimore MARC Station, focusing on various core community development objectives ("About — HUB West Baltimore Community Development Corporation"). The Red Line has the potential to significantly bolster revitalization endeavors in West Baltimore communities like Edmondson Village by enhancing accessibility to job centers and local resources. This improved transit system could attract more visitors and potential patrons to local businesses, thereby supporting economic rejuvenation. Furthermore, the Red Line can connect residents to job opportunities within and around the city, fostering local business growth through increased foot traffic, and attracting new investments to the area. By improving connectivity between communities and offering an eco-friendly travel alternative, the Red Line aligns with broader urban sustainability goals, potentially acting as a catalyst for community revitalization, economic mobility, and improved living standards in West Baltimore.

Policy Recommendations

The transformative potential of the Red Line extends beyond its immediate impact on job accessibility. While it is poised to be a pivotal infrastructure development, its efficacy can be maximized only when it becomes part of a more robust, integrated transit system.

Firstly, as our findings in the "Connecting Routes" section suggest, extending more transit routes to intersect with Red Line stations can broaden the project's reach, serving communities that are beyond walking distance from the Red Line. This is particularly significant for neighborhoods like Greater Rosemont, which could become central transit hubs, linking various parts of the city.

Secondly, the "Inaccessible Job Center" section of our study reveals a missed opportunity to link key job centers directly to Red Line stations. One glaring example is the Chesapeake Commerce Center. Bridging this connectivity gap could further amplify the Red Line's impact on job accessibility across Baltimore. We recommend the establishment of direct shuttle services or feeder buses from Red Line stations to these job centers.

Thus, we call for a more integrated transit policy that considers the Red Line not as a standalone project but as a key component of a city-wide transit ecosystem. This should include the development of multi-modal transit solutions, such as feeder buses, shuttles, and bike-sharing programs that connect with Red Line stations, as well as policies to protect vulnerable communities from potential gentrification risks.

Moreover, we emphasize that the potential benefits of the Red Line heavily depend on its ability to offer frequent, reliable service that meets the needs of commuters. In 2023, the Maryland Light Rail saw a decline in ridership after a nearly yearlong service disruption. The effects of past disruptions have been noted by riders, who experienced issues like arriving late to work or being stranded at night after events. While on-time performance metrics have begun to rebound, ridership on the light rail dropped off earlier this year, contrasting with ridership increases in other forms of public transit. State transit service might

have alienated riders due to service changes over several months (Miller). With frequent, reliable services, the Red Line project offers an opportunity to restore faith from the commuters.

Lastly, as with any significant infrastructure project, ongoing assessment is vital. The city should commit to regular evaluations of the Red Line's impact and be prepared to adapt its policies and connecting routes based on these findings. A steadfast governmental commitment to improving transit infrastructure is the most feasible way to foster robust transit systems (Bloom, 2023, p. 289).

Methods and Data

Transit Time Analysis

The analysis leverages a combination of datasets: OpenStreetMap (OSM) (GEOFABRIK), the Maryland Transit Administration's General Transit Feed Specification (GTFS) dataset from MTA Developer Resources ("Developer Resources|Maryland Transit Administration"), Transitland Source Feed (Transitland), and the Adherence + Reliability + Integrity Evaluation System (ARIES) (Pizzurro & Pizzurro).

OpenStreetMap and GTFS Datasets: Our multimodal transportation network fuses transit and walking networks, sourced from the OSM file and the Maryland Transit Administration's GTFS dataset. The GTFS dataset, a standardized format adopted by transit agencies, provides detailed insights into transit services, as well as the scheduled vehicular timings. The specific GTFS data for this study was extracted from the Transitland Source Feed, which maintains historical GTFS feeds published by the Maryland Transit Administration, capturing the evolving nature of bus schedules in Baltimore City.

Real-time Bus Data and ARIES: To incorporate the historical delay patterns endemic to public transit, we integrated data from the ARIES system. This dataset encompasses the time period between January 1st and May 31st, 2023, excluding weekends and US holidays, resulting in an analysis of 104 weekdays. Due to the lack of reliable data reflecting when commuters travel in Baltimore, we filtered trips that had their last scheduled stop post 8 am and the initial stop pre 10 am, assuming that most jobs may still pertain to a nine-to-five working schedule. In our job accessibility computations, we include all potential transit options available to commuters at 8 am. These options consider a maximum wait time of 10 minutes and a total transit itinerary under 90 minutes. For imputation of missing data in the observed bus dataset, further details are provided in later sections. For other modes of transit, such as the subway, light rail, and regional rails, where real-time data was not accessible, we relied on the scheduled GTFS datasets, recognizing the potential discrepancy between scheduled and actual transit times.

Red Line Simulation: A hypothetical GTFS dataset was developed for the proposed Red Line. In our model, we assume the train would travel at 20 miles per hour and would arrive at each station every 8 minutes. The first train of the day would start at 7:00 AM.

R5 Python Package and Computation: Utilizing the r5 Python package, we computed hypothetical transit trips and established a travel time matrix. This matrix measures public transit time between every origin and destination point, specifically during the morning peak window starting at 8:00 AM. From this matrix, we select the median travel time as the representative value for job accessibility. This calculation considers the ride time, walking time to and from transit stops, and waiting time determined by the specific bus route's frequency. We repeated this analysis for each of the aforementioned 104 days to capture the day-to-day variability in job accessibility for a typical morning commuter in Baltimore City. The code for this analysis can be accessed at: https://github.com/Xieyangxinyu/Red-Line-Simulation.

Job Accessibility

Economic vitality and the overall quality of life in urban areas hinge on the ease with which residents can access employment opportunities. Effective job accessibility can lead to lower unemployment rates, broader economic opportunities, and underpin sustainable urban growth. To assess the proposed Red Line's impact, we have adopted job accessibility as a key metric, given its proven significance in transit-related studies.

For this study, we have sourced job datasets from the Census Bureau's Longitudinal Employer and Housing Dynamics (LEHD). Following recent studies (Barri et al., 2021), we employ a gravity-based accessibility model. Our method calculates the ease of accessing jobs from a specific location, considering various transit-related factors. These include the walking duration to and from transit stops, the waiting time for the vehicle, the time spent on the vehicle, and any necessary transfer times. The more jobs one can reach within a short commute, the higher the job accessibility score for that location.

At its core, gravity-based job accessibility is inspired by the law of gravity in physics, where the attraction between two objects is determined by their mass and distance. Translated to urban transit and job access, this concept gauges the 'attraction' or accessibility of jobs based on the 'mass' (number of jobs) and the 'distance' (transit time). Simply put, a location close to numerous jobs will have high accessibility, but as transit time increases, the attraction (or accessibility score) diminishes.

Mathematically, the job accessibility score A_i for census block i is

$$A_i = \sum_{j=1}^{J} n_j \, f(t_{i,j})$$

where n_j is the number of jobs in census block j, $t_{i,j}$ is the travel time between census block i and census block j, and $f(t_{i,j})$ is the impedance function used to model the diminishing attraction of jobs with travel time. The impedance function ensures that jobs farther away contribute less to the accessibility score than those closer and is defined as

$$f(t_{i,j}) = \frac{2\, t_{thresh}}{t_{thresh} + t_{i,j}} - 1, if \;\; t_{i,j} < t_{thresh}, \;\; and \;\; f(t_{i,j}) = 0, \qquad otherwise,$$

where we set the maximum travel time value t_{thresh} to be 30 or 45 minutes. These values are common preferences in the population for maximum commute times and follow the assumptions made in previous studies (Baltimore Transit Equity Coalition, 2021; Fan, Guthrie, & Levinson, 2012; Klar, Lee, Long, & Diab, 2023). In this report, job accessibility is calculated for mid-to-lower income jobs. Our accessibility computations quantify the number of such jobs reachable from each block centroid within a stipulated travel time threshold, adjusting for the decrease in job attraction with increased commute time within this threshold.

Handling Missing Data in Real-Time Bus Information

To ensure the accuracy of our analysis on the proposed Red Line to Baltimore City, we had to address instances where real-time bus arrival data was missing. Our approach is twofold:

Simple Imputation for Minor Data Gaps

Criteria: If only a few data points are missing for a specific bus route during a single journey, we estimate these missing times.
Method: We use the time and distance between known data points to calculate the missing arrival times.

Exception: If the first data point for a journey is missing, we use the bus's scheduled arrival time as an estimate.

Replacement Method for Major Data Gaps

Criteria: If a significant number of data points are missing for a particular bus route during a journey—more than a predefined threshold—we use a different approach.
Method: For these cases, we select data from another day where the same bus route had complete data and use this as a substitute.

Caveats

It is important to note that there could be legitimate reasons for missing data. For instance, a bus may have skipped a stop or the trip could have been canceled. These factors could potentially affect the wait times for passengers, but they are outside the scope of this study.

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