

Case Study

Overview: The National Capital Region Transportation Planning Board (TPB) conducted five benefit-cost analysis (BCA) case studies of transportation assets within the National Capital Region to demonstrate the cost of inaction, compare low-cost and high-cost solutions, and provide support for the benefits of proactive resilience investment.

Study Site: The focus of this case study is the Washington Metropolitan Area Transit Authority (WMATA) Metrorail section between Loudoun Gateway and Washington Dulles International Airport. This section of the Silver Line sees roughly 5,000 passengers per day through Dulles Station.ⁱ

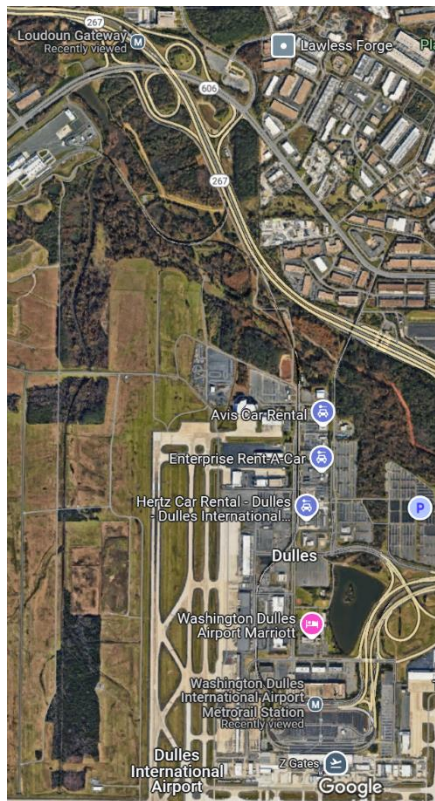
Context: The outdoor sections of the WMATA metro are at significant risk from extreme heat.ⁱⁱ A sun kink, or heat kink, may occur when the metal rails expand in high temperatures and prolonged direct sunlight. Sun kinks pose a safety hazard because they can lead to warping of the track and in extreme cases, train derailments. To avoid these impacts, there are strict speed limits imposed on trains traveling during extreme heat events to mitigate track stress and increase safety.ⁱⁱⁱ These enforced slowdowns generate delays and increase travel time which can severely impact commuters and passengers traveling to the airport.

Results: BCA results suggest that the low-cost and high-cost solutions have discounted (3.1%)^{iv} benefit-cost ratios of 1.21 and 0.13, respectively. These results imply that for every \$1 invested, the low-cost solution will return about \$1.21 in heat damage prevention benefits. The high-cost solution would result in about \$0.13 in heat damage benefits per dollar invested.

Methods: The analysis assumes that heat events severe enough to require trains to operate at slower speeds represent about 20% of the 80 annual heat event days the area experiences on average. Based on several years of

Key Takeaways

- Extreme heat poses a risk of track warping, necessitating metro and rail car slowdowns that cause delays and increase travel time.
- Based on this analysis, investment in a low-cost rail painting solution could lead to benefits at a rate of \$1.21 per dollar invested.
- Similar action could be taken at a regional level for key or at-risk metro- or rail-lines, significantly reducing the impacts of extreme heat days on public transit riders in the National Capital Region.



Metrorail Silver Line Near Dulles Airport Station (Google Maps)



temperature data captured at the Dulles Airport Station, this number of heat event days is expected to increase by 3.61% each year, or 2.89 additional days annually ($80 \times 3.61\%$).^v The main costs of not acting proactively on heat impacts are the additional cost of time that riders experience onboard the Metrorail due to slowed speeds, and the replacement of track due to eventual warping. Usually, Metrorail trains on the Silver Line are estimated to operate at 65 miles per hour (MPH). During heat-related speed restrictions, speeds are reduced by 54% to 35 MPH.^{vi} The typical 7-minute trip from Loudoun Gateway to Dulles Airport Station (and vice versa) becomes approximately 13 minutes (7 minutes / 54%), for an incremental time of 6 additional minutes. Based on 5,000 daily passengers and a value of travel time of \$21.72 per hour,^{vii} the time cost of these 6 minutes for all passengers per day is approximately \$11,000. The cumulative annual cost consists of \$11,000 per day, multiplied by 20% of heat event days that cause speed restrictions, and 2.89 cumulative additional heat event days per year. In total, the annual value of time cost to passengers of heat events is about \$6,300. This analysis also assumes there is a 1% annual risk, and 0.01% cumulative risk,^{viii} of heat-induced track failure warranting track replacement and reducing travel to a single track. Single tracking is assumed to endure for 3 weeks, during which time 10 minutes is added to travel time per passenger. Based on the 2024 value of travel time, 3 weeks (21 days) of delay, 5,000 daily passengers, and 10 minutes (1/6th of an hour) of delay, the total value of time for delays during track replacement is about \$380,000. Two hundred feet of track is assumed to be replaced. Based on a replacement cost of \$300,000 per mile^x (5,280 feet), the cost to replace 200 feet of track is estimated at \$11,400. The total annualized cost of track replacement, including both passenger time delay and track replacement, based on the 1% annual risk and 0.01% cumulative risk, is about \$3,900.

This analysis proposes a low-cost and high-cost solution, intended to reduce or even theoretically eliminate heat-related rail impacts, respectively. For the low-cost solution, this analysis assumes 2 miles of rail near Dulles Airport Station are painted white at a cost of about \$56,000,^x reducing the average temperature of the track. The analysis assumes this action decreases the number of days with Metrorail speed restrictions by 25%, saving approximately \$1,600 annually in passenger delays. The high-cost solution requires full proactive replacement of 2 miles of track with “heat-immune rails,” which are assumed to be 25% more expensive than standard rails, for a total capital cost of about \$750,000.^{xi} This portion of rail is subjected to single tracking for 3 weeks while each track is replaced, leading to about \$380,000 in passenger delays. The total cost of the high-cost solution, including both passenger delay and track replacement, is about \$1.1 million. The heat-immune rails are assumed to eliminate speed restrictions during heat events for this portion of track.

Detailed Results: Over 20 years, the total costs of no action near Dulles Airport Station consist of approximately \$878,000 in passenger delay time costs due to speed restrictions and about \$57,800 in track replacement costs, for a total net cost of about \$935,000 (discounted at 3.1%). Metrorail speed restriction mitigation in the low-cost solution would lead to about \$38,000 (discounted at 3.1%) in net benefits over 20 years. The high-cost solution, in which 2 miles of rail would be proactively replaced, is estimated to result in \$150,000 in avoided delay and track warping benefits, resulting in about \$980,000 in net costs over 20 years with a BCR of 0.13, discounted at 3.1%.

Qualitative Benefits: The potential investments explored here would likely produce other benefits that were not quantified by this analysis. For example, passengers that may be deterred by slower travel times during heat-induced speed restrictions may turn to other forms of transportation, such as personal vehicles or rideshares; eliminating speed restrictions can induce those passengers back to mass transit, thus reducing the emissions and congestion related to private vehicles.

This analysis includes a detailed benefit cost analysis model assessing quantified costs and benefits. For additional information on this case study, or to assess your own site for transportation resilience, please reach out to Katherine Rainone at krainone@mwkog.org.

Regional Implications: During heat events, the entirety of the Metrorail system is often subjected to speed restrictions. Other portions of the Metrorail tracks could benefit from heat mitigation measures, in particular other sections of track that are similarly exposed to direct sunlight. Painting Metrorail tracks white is a cost-effective way to reduce rail temperatures and avoid heat-related speed restrictions. Because the cost per mile of track painted would stay approximately the same regardless of the portion of track to which it is applied, the more passengers a section of track experiences, the greater the cost savings. Areas of the Metrorail or other National Capital Region rail systems that experience both high ridership and exposure to direct sunlight are most likely to experience the greatest benefits of investment in heat mitigation, like rail painting.

ⁱ WMATA, October 4, 2023. <https://www.wmata.com/about/news/Dulles-one-million-customers.cfm>

ⁱⁱ Rising Risk along the Eastern Seaboard including within National Capital Region:

<https://www.nature.com/articles/s42949-025-00227-7>

ⁱⁱⁱ WMATA, June 20, 2024. <https://x.com/wmata/status/1803857224705675697?lang=en>

^{iv} A discount rate is a rate used to determine the present value of future cash flows. As of 2025, the U.S. Department of Transportation recommends a discount rate of 3.1%.

^v Percentage calculated from Temperatures in Fairfax County since 1924 - Dulles Airport Station,

<https://www.weather.gov/wrh/Climate?wfo=lwx>, Washington DC Du, VA

^{vi} FFXNow, June 20, 2024. <https://www.ffxnow.com/2024/06/20/now-metro-slows-down-trains-due-to-high-temperatures/>

^{vii} Table A-2: Value of Travel Time Savings, [https://www.transportation.gov/sites/dot.gov/files/2024-](https://www.transportation.gov/sites/dot.gov/files/2024-11/Benefit%20Cost%20Analysis%20Guidance%202025%20Update%20%28Final%29.pdf)

11/Benefit%20Cost%20Analysis%20Guidance%202025%20Update%20%28Final%29.pdf. Inflated to 2024 values using suggested values of CPI from BLS: <https://data.bls.gov/pdq/SurveyOutputServlet>

^{viii} In Year 1, the annual risk is 1%, which increases by 0.01% in each subsequent year.

^{ix} Estimated off Purple line and Silver line extension projects. Both projects cost roughly \$5B-\$6B each for 16 mile and 23 mile extensions respectively.

^x Based on \$5 of paint per linear foot, a \$41.44 loaded labor rate (for maintenance and repair worker, general (BLS SOC 49-9099), and 80 hours to complete the work. $\$5 \times 5,280 \text{ feet} \times 2 \text{ miles} + \$41.44 \times 80 \text{ hours} = \$56,115$.

^{xi} $\$300,000 \text{ per mile cost to replace track} \times 1.25 [25\% \text{ additional cost}] \times 2 \text{ miles} = \$750,000$.

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