REGIONAL TRANSPORTATION RESILIENCE ECONOMIC ANALYSIS

Cost-Benefit Analyses of Five Case Study Transportation Assets & Example Resilience Measures

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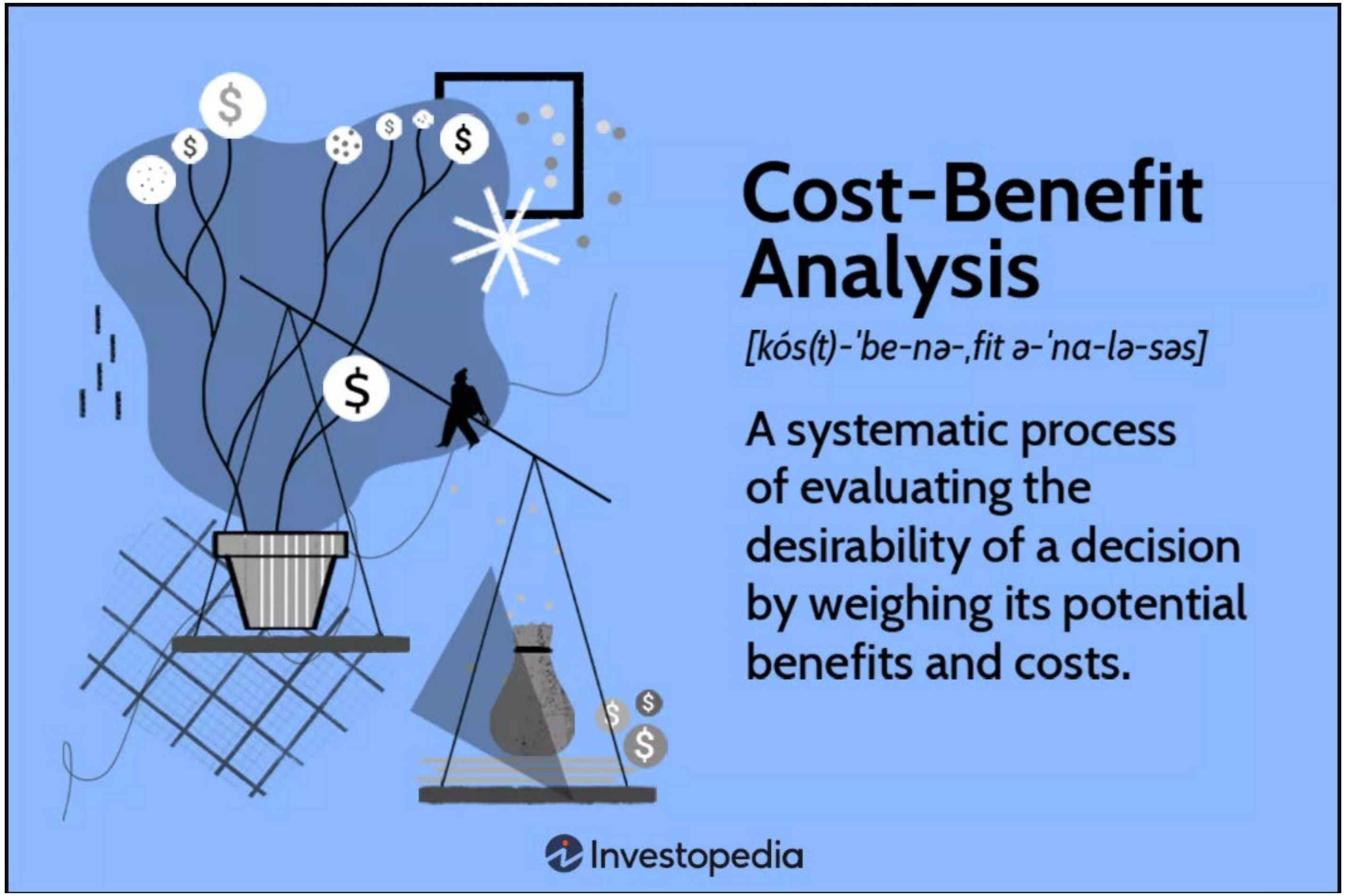
National Capital Region
Transportation Planning Board

Agenda Item 7

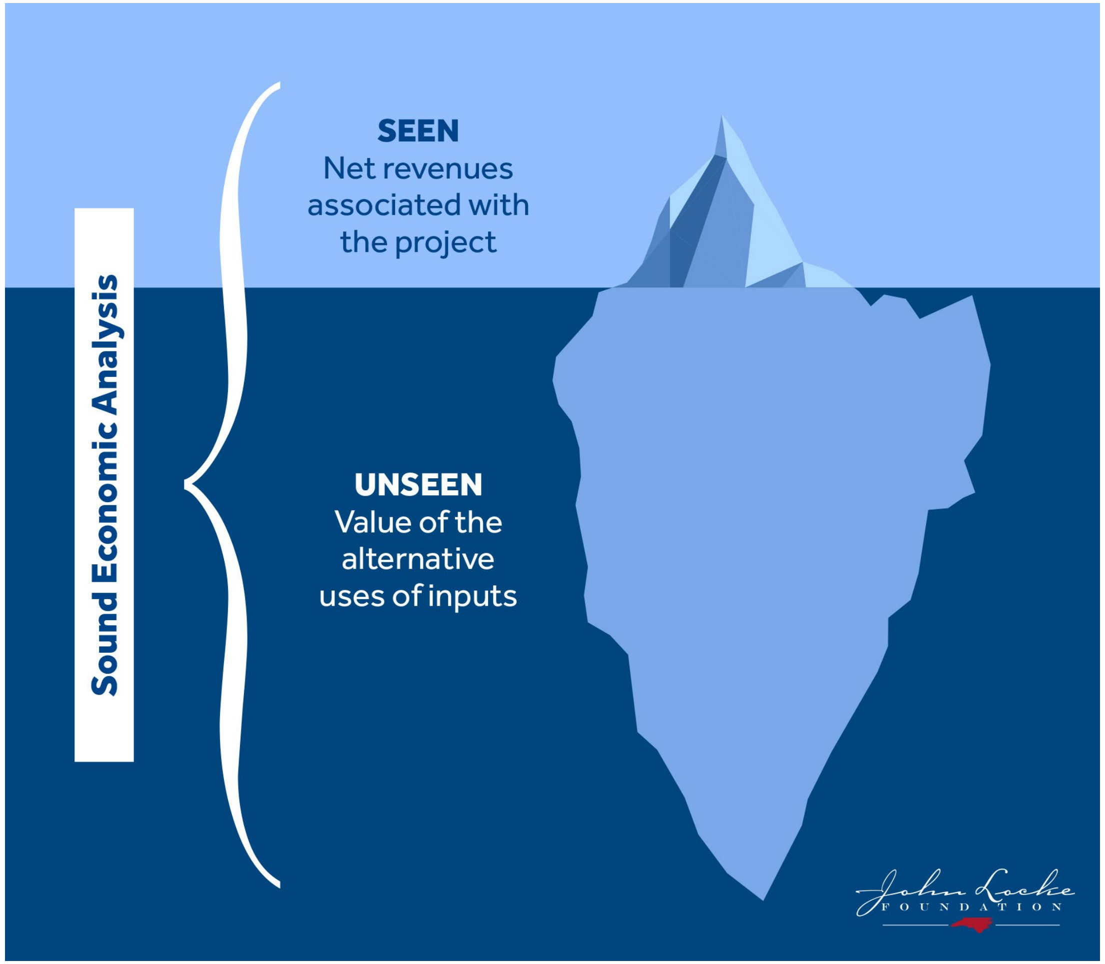
What is a Benefit-Cost Analysis (BCA)?



Graphic by [Investopedia]

Why are BCAs important?

- Improves investment decisions and helps with project prioritization
- Strengthens funding competitiveness
- Makes “avoided losses” visible
- Supports transparent and accountable planning – both short-term and long-term
- Often required for funding applications



Graphic by the John Locke Foundation

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Why are resilience investments important?

- Increasing frequency and severity of flooding, heat, storms, and other hazards
- Growing exposure of transportation assets and system users
- Competing funding priorities within TIPs, LRTPs, CIPs: prioritization assistance
- Bond ratings
- High risk/vulnerability does not always mean high reward

Amount spent on preparedness reduces the economic impact on the local community. Every $1 spent on preparing for disasters is worth $7 in saved economic costs for the community, including job losses, reduced incomes, and other economic impacts.

Disaster preparedness is a good idea in large cities and small communities alike. Investments in resilience and preparedness have large potential benefits in smaller communities whether it's a large $1 billion disaster or a smaller one.

The U.S. averages about 10 $1 billion disasters each year. From 1980 to the present, the U.S. has suffered 383 weather and climate disasters that caused more than $1 billion in damage. Those disasters caused more than $2.7 trillion of damage in total.[3]

Investment in disaster preparedness pays off. Every $1 invested in resilience and preparedness saves $13 in economic savings, damage, and cleanup costs after the event.

Investments in resilience and preparedness have economic benefits even if a disaster never occurs. As investments in disaster preparedness climb, communities see more jobs, the workforce grows, more people move to the area, and production and incomes increase.

The Preparedness Payoff: The Economic Benefits of Investing in Climate Resilience by U.S. Chamber of Commerce

Regional Transportation Resilience Economic Analysis

- Analysis to demonstrate the cost of inaction and provide support for the benefits of proactive resilience investment
- Five case studies quantifying the costs and benefits of resilience and adaptation
- Transportation assets (one each of: rail stops, bus stops, road segments, rail segments, bridges)
- Natural hazards (flooding and extreme heat)
- Develop a framework for risk-based economic impact analysis, and guidance for the evaluation of further assets and projects

Case Studies

- Bus Stop: Army Navy Drive & S. Joyce St stop in Arlington
- Rail Stop: Greenbelt MARC Station
- Bridge: Liverpool Point Road
- Railway: Silver line between Loudon Gateway and Washington Dulles
- Roadway: Anacostia Freeway


Transportation Resilience — Infrastructure: Railway
Transportation Resilience — Road Segment
Transportation Resilience — Infrastructure: Bridge
Transportation Resilience — Transit: Rail Stop

Transportation Resilience — Transit: Bus Stop

Case Study

Overview: The National Capital Region Transportation Planning Board (TPB) is conducting 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.

Key Takeaways

- Shelters and foliage solutions at bus stops can significantly lower ambient temperatures, resulting in decreased health costs.
- Over 20 years, no investment could result in nearly $7,000 in health impacts at a single location.
- Results suggest a 3:1 ROI for proactive investment.
- Similar action could be taken at a regional level to address health concerns in the National Capital Region.

Study Site: The focus of this case study is the Army Navy Drive & South Joyce Street westbound/southbound bus stop in Arlington, VA. This Metrobus and Arlington Transit bus stop serves roughly 70 riders per day and lacks existing shelter or vegetation.

Aerial view, Army Navy Drive/South Joyce Street (Google Maps)

Context: Studies, such as those by the Center for American Progress,[i] show that exposure to extreme heat results in increased emergency department (ED) visits and hospitalizations, and that the number of days with extreme heat is expected to increase. Research published by Arizona's Sun Tran bus service[ii] and Lanza et al. (2025)[iii] shows that shelters and surrounding vegetation can lower ambient and ground temperatures and help mitigate health impacts at bus stops. This case study examines a low-cost solution of erecting a bus shelter and a high-cost solution of supplementing the shelter with additional trees and foliage to lower temperatures around the stop. In addition, the new bus shelter would provide space for advertising, thereby producing advertising revenue.

Bus stop with shelter (klllane/Shutterstock)

Results: BCA results suggest that the low-cost and high-cost solutions have discounted (3.1%)[iv] benefit-cost ratios of 3.0 and 2.7, respectively. These results imply that for every $1 invested in solutions, there is a return of nearly $3 in health and advertising revenue benefits. Net benefits are estimated at around $100,000 over 20 years.

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Case Study: Bus Stop
Army Navy Drive & S. Joyce St stop in Arlington

Impacts of Extreme Heat on Bus Commuters

Inputs:
- Ridership
- Heat-related emergencies
- Cost of heat-related health emergencies
- Heat days

Solutions:
- No Action
- Low-Cost – bus shelter solution
- High-Cost – bus shelter plus vegetation solution

Transportation Resilience **Transit: Bus Stop**

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Bus stop with shelter (klllane/Shutterstock)

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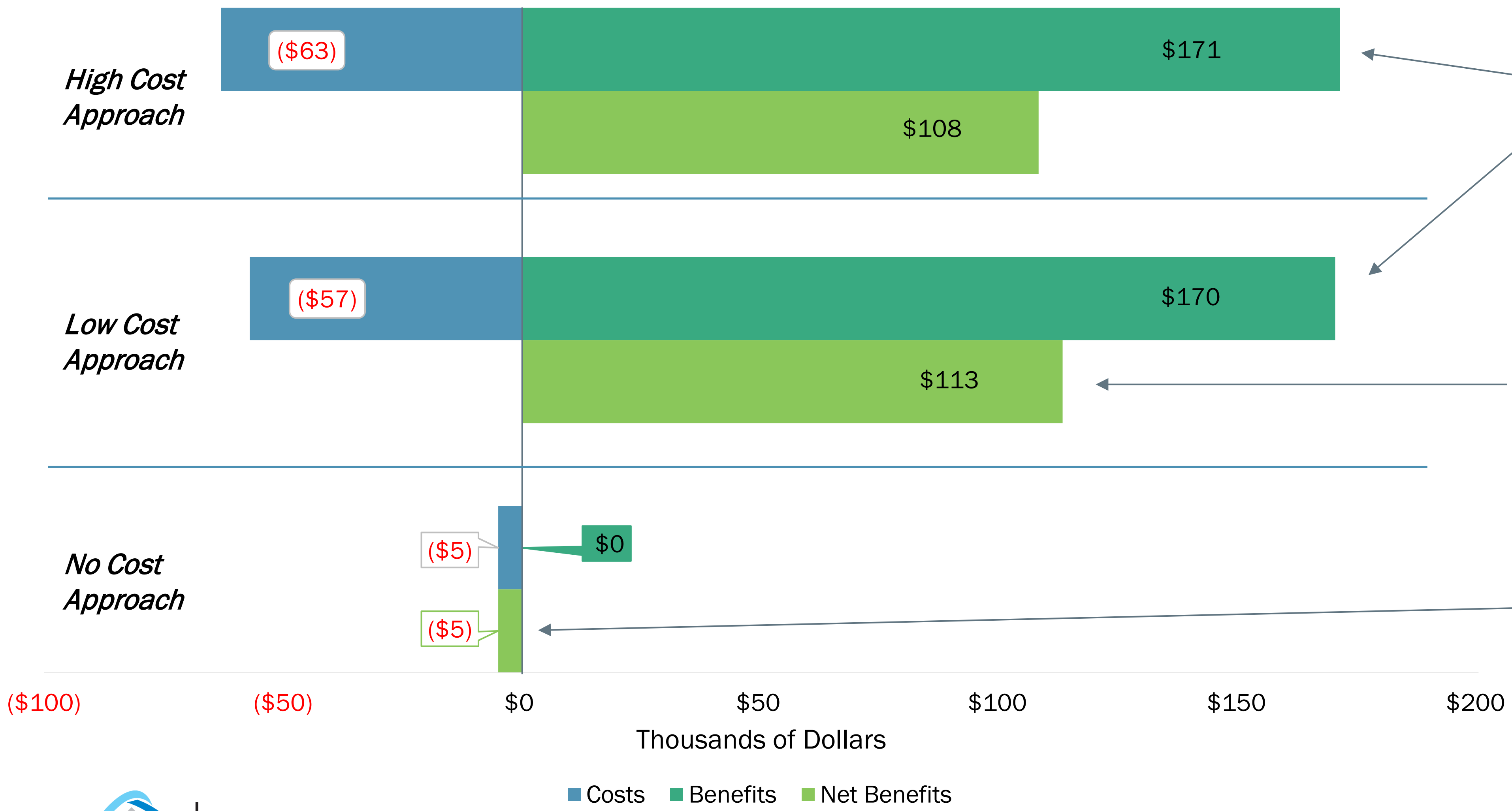
Cost Comparison, Bus Stop Investment Approaches (Discounted 3.1%)



The **Low Cost approach** yields *similar benefits to the High Cost approach at a lower cost.*

The **Low Cost approach** also has the highest net benefits.

Lack of investment could cost $5,000 over 20 years.

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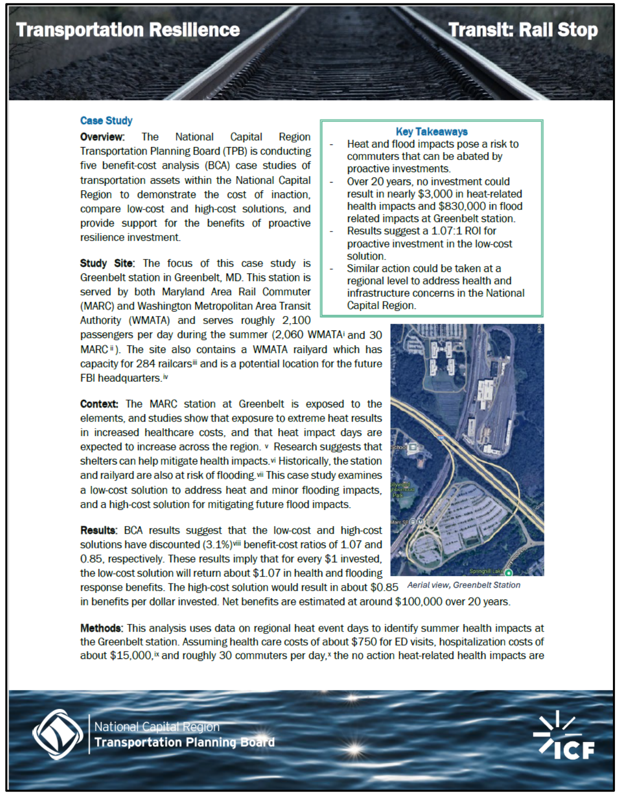
Case Study: Rail Stop
Greenbelt MARC Station in Maryland

Impacts of Heat and Flooding on MARC Commuters

Inputs:
- Ridership
- Heat days
- Heat-related emergencies
- Risk of heat-related track failure
- Nuisance flooding

Solutions:
- No Action
- Low-Cost – Temporary signage, pumps for nuisance flooding
- High-Cost – Shelter for heat, track hardening eliminates track flooding entirely



Transportation Resilience — **Transit: Rail Stop**

Case Study

Overview: The National Capital Region Transportation Planning Board (TPB) is conducting 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.

Key Takeaways
- Heat and flood impacts pose a risk to commuters that can be abated by proactive investments.
- Over 20 years, no investment could result in nearly $3,000 in heat-related health impacts and $830,000 in flood related impacts at Greenbelt station.
- Results suggest a 1.07:1 ROI for proactive investment in the low-cost solution.
- Similar action could be taken at a regional level to address health and infrastructure concerns in the National Capital Region.

Study Site: The focus of this case study is Greenbelt station in Greenbelt, MD. This station is served by both Maryland Area Rail Commuter (MARC) and Washington Metropolitan Area Transit Authority (WMATA) and serves roughly 2,100 passengers per day during the summer (2,060 WMATA[i] and 30 MARC[ii]). The site also contains a WMATA railyard which has capacity for 284 railcars[iii] and is a potential location for the future FBI headquarters.[iv]

Context: The MARC station at Greenbelt is exposed to the elements, and studies show that exposure to extreme heat results in increased healthcare costs, and that heat impact days are expected to increase across the region.[v] Research suggests that shelters can help mitigate health impacts.[vi] Historically, the station and railyard are also at risk of flooding.[vii] This case study examines a low-cost solution to address heat and minor flooding impacts, and a high-cost solution for mitigating future flood impacts.

Aerial view, Greenbelt Station

Results: BCA results suggest that the low-cost and high-cost solutions have discounted (3.1%)[viii] benefit-cost ratios of 1.07 and 0.85, respectively. These results imply that for every $1 invested, the low-cost solution will return about $1.07 in health and flooding response benefits. The high-cost solution would result in about $0.85 in benefits per dollar invested. Net benefits are estimated at around $100,000 over 20 years.

Methods: This analysis uses data on regional heat event days to identify summer health impacts at the Greenbelt station. Assuming health care costs of about $750 for ED visits, hospitalization costs of about $15,000,[ix] and roughly 30 commuters per day,[x] the no action heat-related health impacts are

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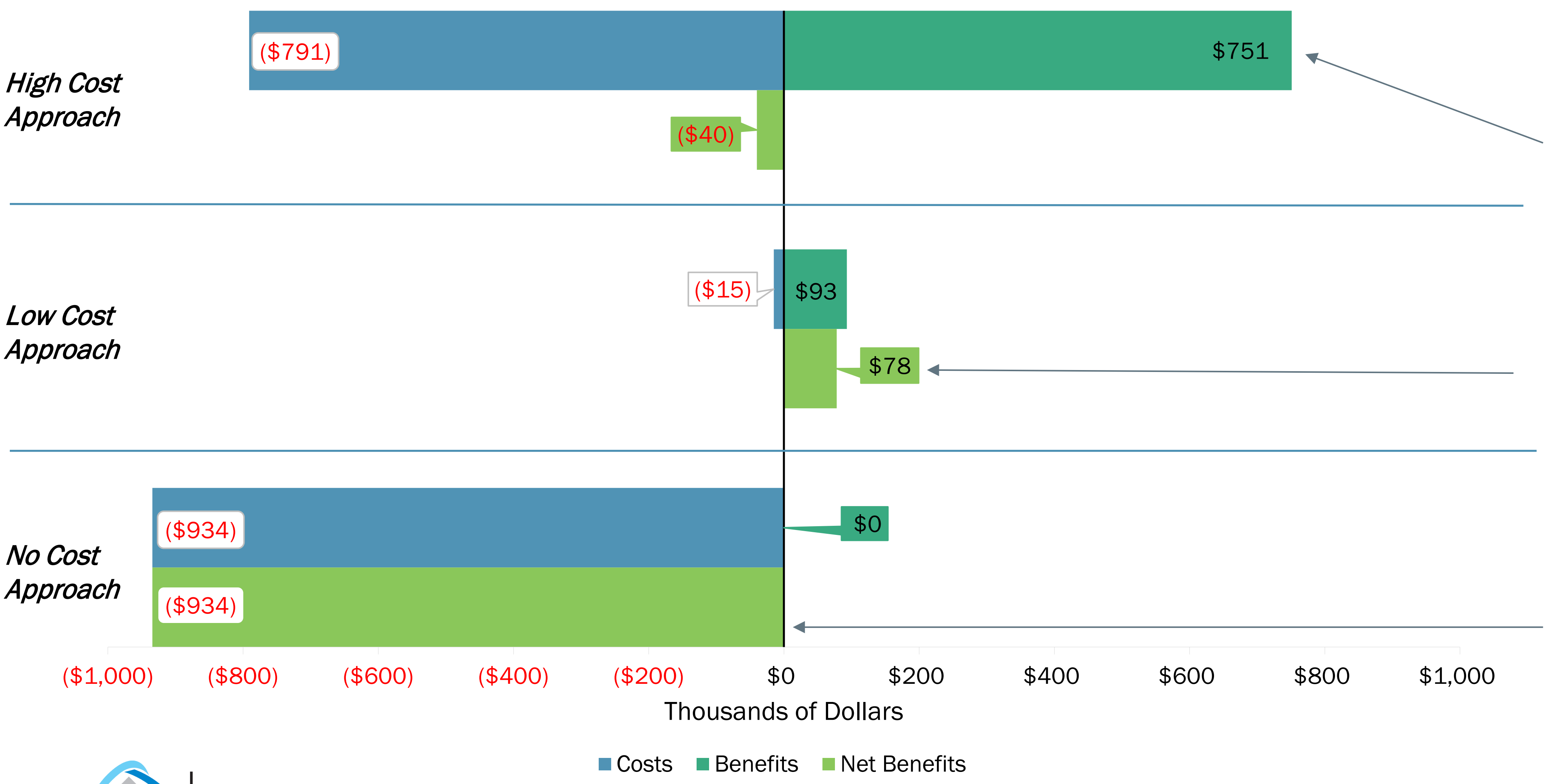
Cost Comparison, Rail Stop Investment Approaches (Discounted 3.1%)



The **High Cost approach** yields the highest benefits, but costs more than it would save.

The **Low Cost approach** offers the highest net benefits.

Noninvestment could cost over $900,000 over 20 years.

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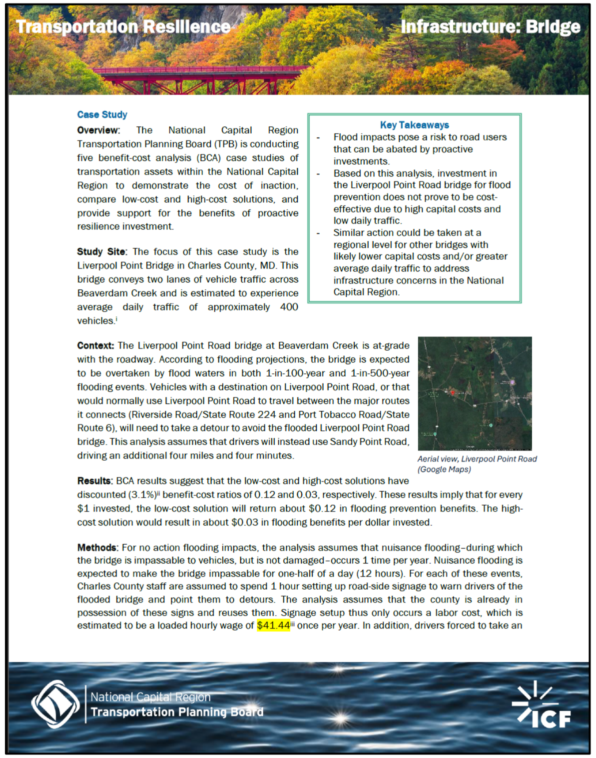
Case Study: Bridge
Liverpool Point Road in Charles County, MD

Impacts of Flooding on Road Users

Inputs:
- Average Annual Daily Traffic
- Frequency and length of flooding-related bridge closures

Solutions:
- No Action
- Low-Cost – Embankment hardening
- High-Cost – Full bridge replacement



Transportation Resilience **Infrastructure: Bridge**

Case Study

Overview: The National Capital Region Transportation Planning Board (TPB) is conducting 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 Liverpool Point Bridge in Charles County, MD. This bridge conveys two lanes of vehicle traffic across Beaverdam Creek and is estimated to experience average daily traffic of approximately 400 vehicles.[i]

Key Takeaways
- Flood impacts pose a risk to road users that can be abated by proactive investments.
- Based on this analysis, investment in the Liverpool Point Road bridge for flood prevention does not prove to be cost-effective due to high capital costs and low daily traffic.
- Similar action could be taken at a regional level for other bridges with likely lower capital costs and/or greater average daily traffic to address infrastructure concerns in the National Capital Region.

Context: The Liverpool Point Road bridge at Beaverdam Creek is at-grade with the roadway. According to flooding projections, the bridge is expected to be overtaken by flood waters in both 1-in-100-year and 1-in-500-year flooding events. Vehicles with a destination on Liverpool Point Road, or that would normally use Liverpool Point Road to travel between the major routes it connects (Riverside Road/State Route 224 and Port Tobacco Road/State Route 6), will need to take a detour to avoid the flooded Liverpool Point Road bridge. This analysis assumes that drivers will instead use Sandy Point Road, driving an additional four miles and four minutes.

Aerial view, Liverpool Point Road (Google Maps)

Results: BCA results suggest that the low-cost and high-cost solutions have discounted (3.1%)[ii] benefit-cost ratios of 0.12 and 0.03, respectively. These results imply that for every $1 invested, the low-cost solution will return about $0.12 in flooding prevention benefits. The high-cost solution would result in about $0.03 in flooding benefits per dollar invested.

Methods: For no action flooding impacts, the analysis assumes that nuisance flooding–during which the bridge is impassable to vehicles, but is not damaged–occurs 1 time per year. Nuisance flooding is expected to make the bridge impassable for one-half of a day (12 hours). For each of these events, Charles County staff are assumed to spend 1 hour setting up road-side signage to warn drivers of the flooded bridge and point them to detours. The analysis assumes that the county is already in possession of these signs and reuses them. Signage setup thus only occurs a labor cost, which is estimated to be a loaded hourly wage of $41.44[iii] once per year. In addition, drivers forced to take an

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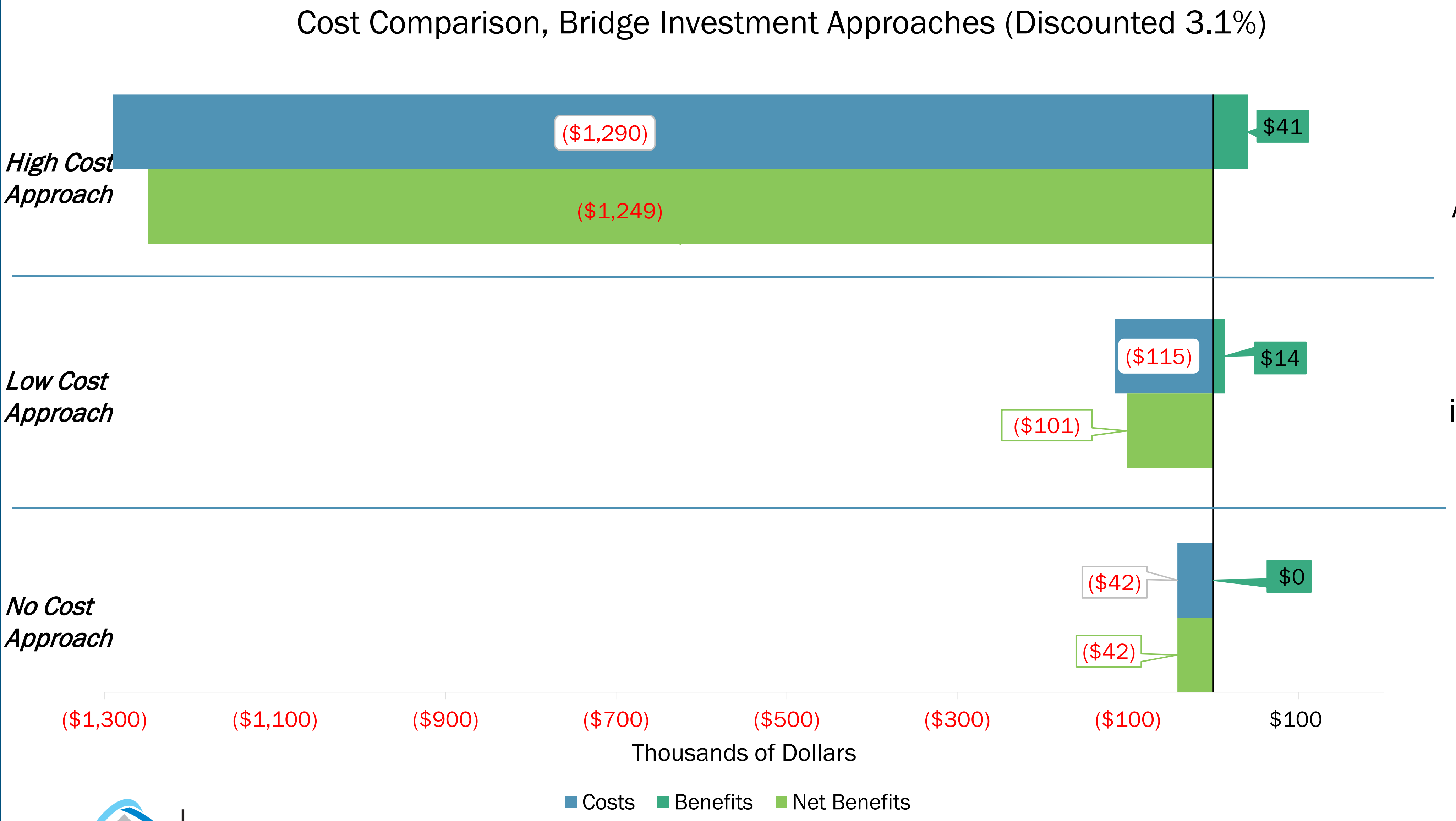

A unique result among our case studies, none of the proposed investments for the Liverpool Point Road bridge were estimated to be cost-beneficial.

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Case Study: Rail Segment Silver Line in Dulles

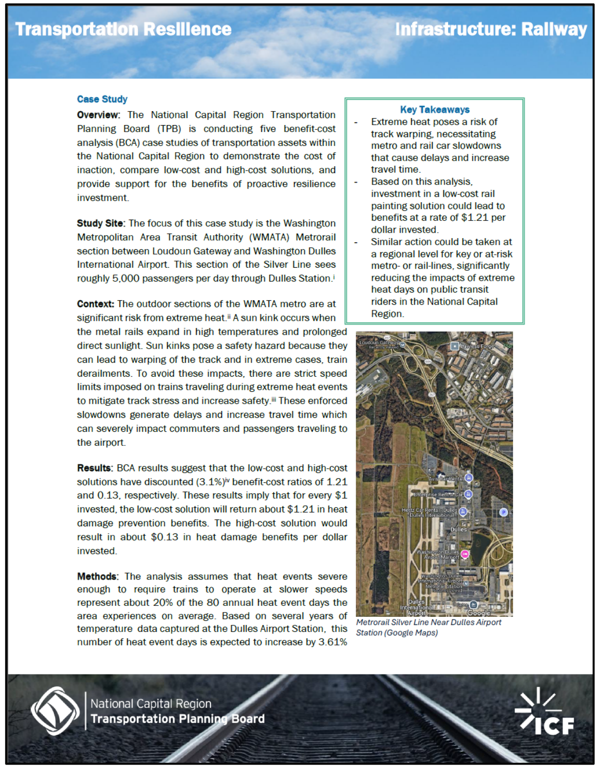
Impacts of Extreme Heat on Rail Commuters

Inputs:

- Ridership
- Heat days
- Value of travel time

Solutions:

- No Action
- Low-Cost – existing rails are painted white
- High-Cost – installation of heat-resistant rails



Transportation Resilience — **Infrastructure: Railway**

Case Study

Overview: The National Capital Region Transportation Planning Board (TPB) is conducting 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 occurs 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 temperature data captured at the Dulles Airport Station, this number of heat event days is expected to increase by 3.61%

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)

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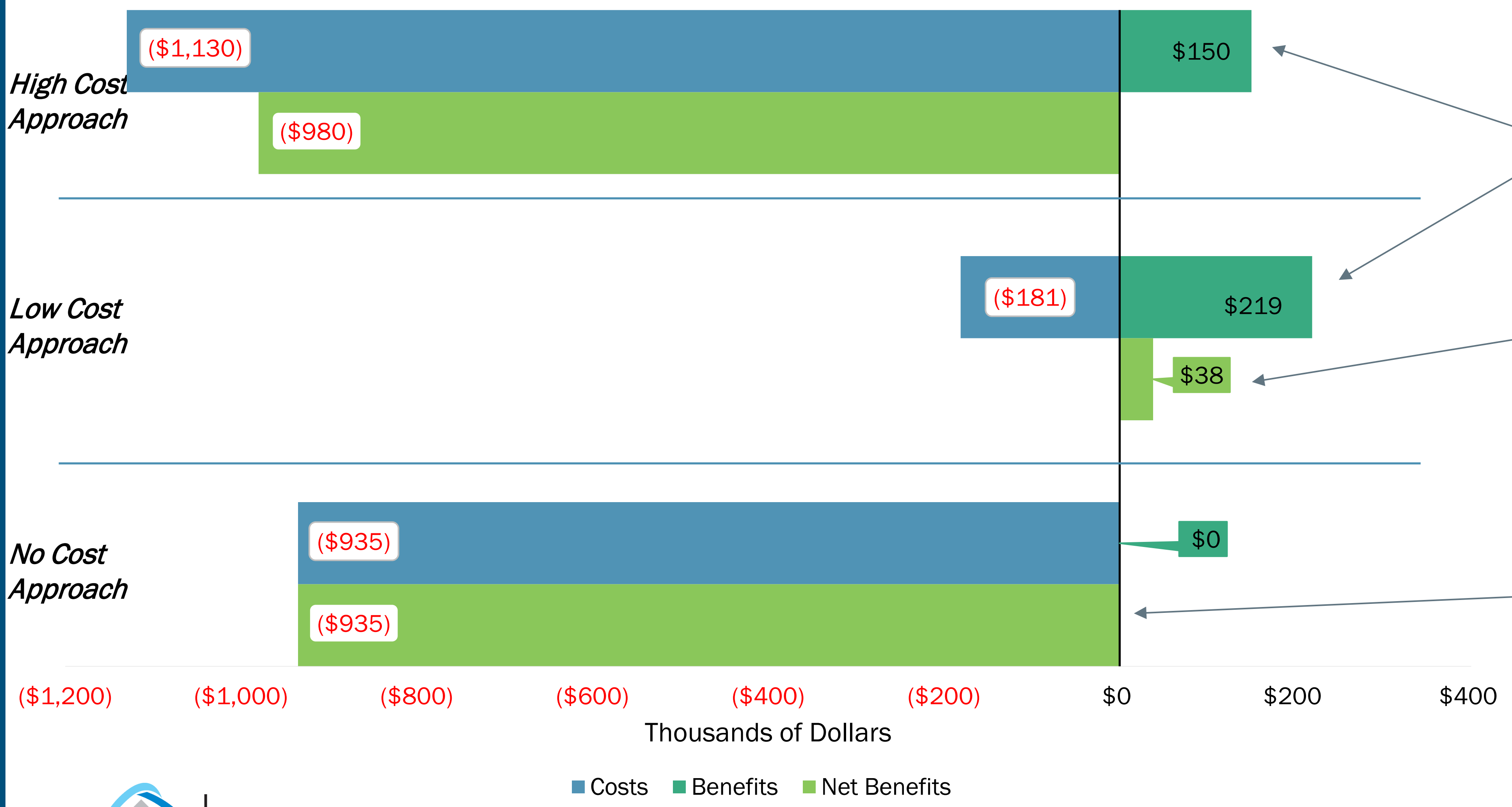
Cost Comparison, Rail Segment Investment Approaches (Discounted 3.1%)



The **Low Cost approach** yields *higher benefits* than the High Cost approach at a *lower cost,* leading to a higher net benefit.

Lack of investment could cost over $900,000 over 20 years.

Case Study: Road Segment Anacostia Freeway in Washington

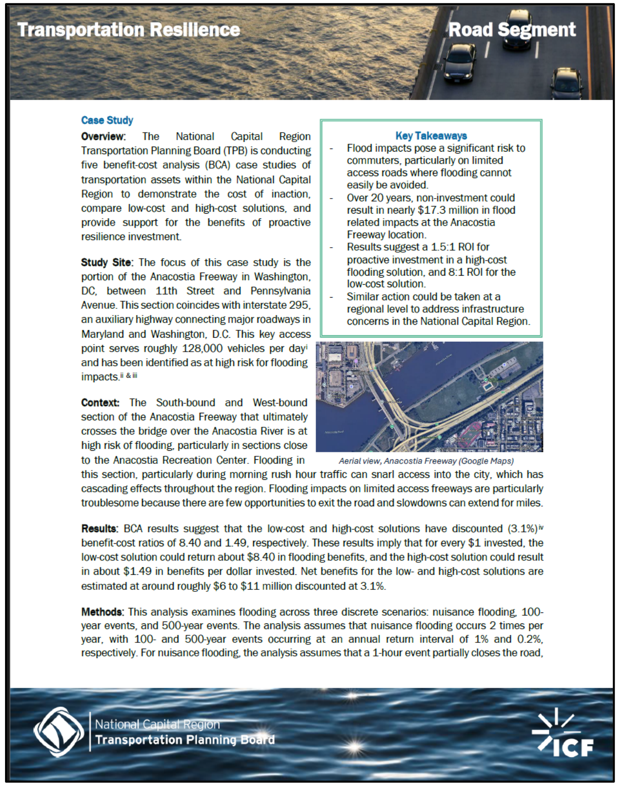
Impacts of Flooding on Road Users

Inputs:

- Average Annual Daily Traffic
- Frequency and duration of roadway flooding
- Value of travel time
- Cost of road closure

Solutions:

- No Action
- Low-Cost – semi-permanent deployable flood barrier
- High-Cost – permanent raising of road



Transportation Resilience | **Road Segment**

Case Study

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Key Takeaways

- Flood impacts pose a significant risk to commuters, particularly on limited access roads where flooding cannot easily be avoided.
- Over 20 years, non-investment could result in nearly $17.3 million in flood related impacts at the Anacostia Freeway location.
- Results suggest a 1.5:1 ROI for proactive investment in a high-cost flooding solution, and 8:1 ROI for the low-cost solution.
- Similar action could be taken at a regional level to address infrastructure concerns in the National Capital Region.

Study Site: The focus of this case study is the portion of the Anacostia Freeway in Washington, DC, between 11th Street and Pennsylvania Avenue. This section coincides with interstate 295, an auxiliary highway connecting major roadways in Maryland and Washington, D.C. This key access point serves roughly 128,000 vehicles per day[i] and has been identified as at high risk for flooding impacts.[ii & iii]

Aerial view, Anacostia Freeway (Google Maps)

Context: The South-bound and West-bound section of the Anacostia Freeway that ultimately crosses the bridge over the Anacostia River is at high risk of flooding, particularly in sections close to the Anacostia Recreation Center. Flooding in this section, particularly during morning rush hour traffic can snarl access into the city, which has cascading effects throughout the region. Flooding impacts on limited access freeways are particularly troublesome because there are few opportunities to exit the road and slowdowns can extend for miles.

Results: BCA results suggest that the low-cost and high-cost solutions have discounted (3.1%)[iv] benefit-cost ratios of 8.40 and 1.49, respectively. These results imply that for every $1 invested, the low-cost solution could return about $8.40 in flooding benefits, and the high-cost solution could result in about $1.49 in benefits per dollar invested. Net benefits for the low- and high-cost solutions are estimated at around roughly $6 to $11 million discounted at 3.1%.

Methods: This analysis examines flooding across three discrete scenarios: nuisance flooding, 100-year events, and 500-year events. The analysis assumes that nuisance flooding occurs 2 times per year, with 100- and 500-year events occurring at an annual return interval of 1% and 0.2%, respectively. For nuisance flooding, the analysis assumes that a 1-hour event partially closes the road,

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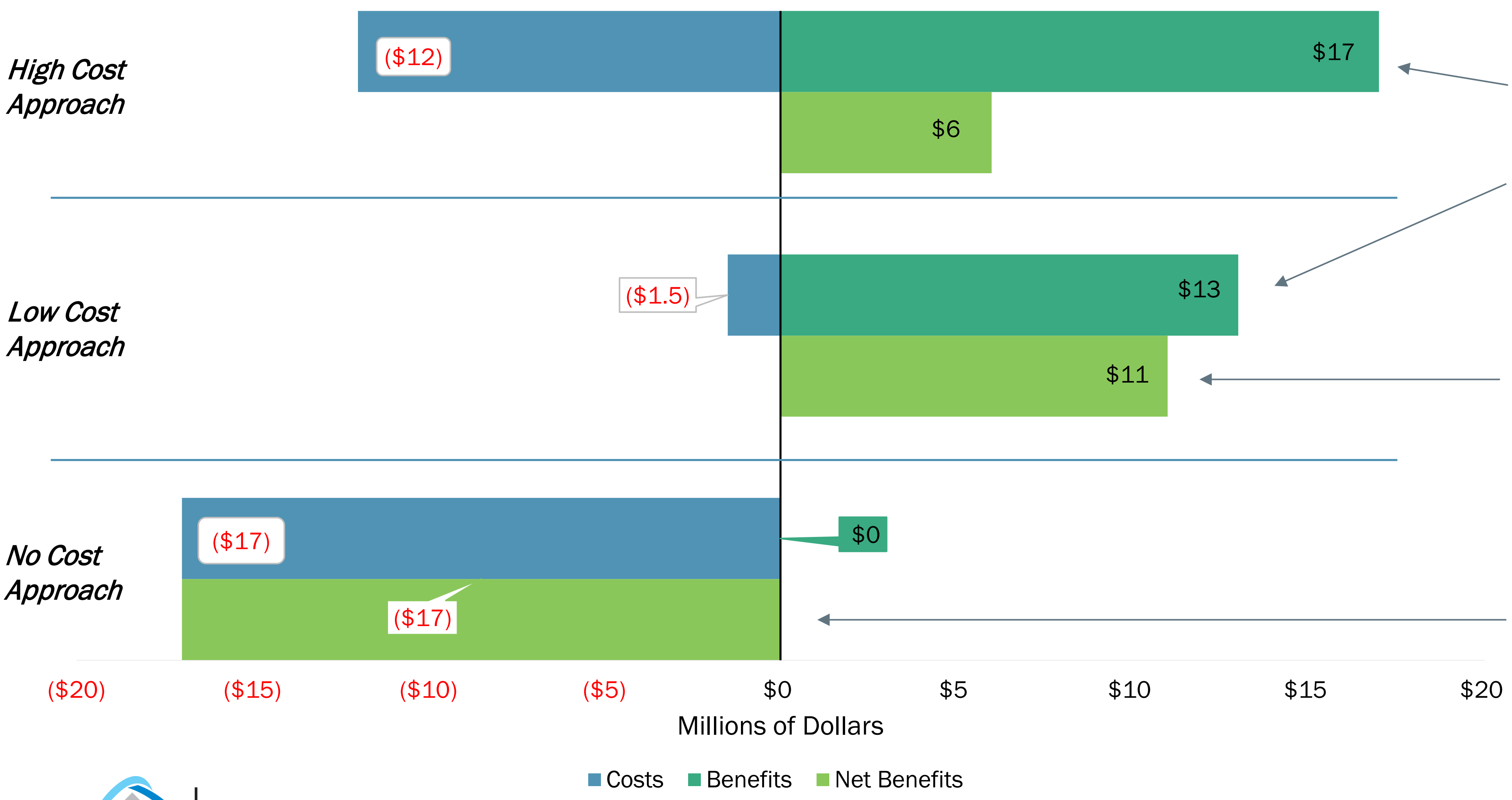
Cost Comparison, Roadway Investment Approaches (Discounted 3.1%)



The **Low Cost approach** yields *similar benefits* to the High Cost approach at a *lower cost*.

The **Low Cost approach** also has the highest net benefits.

Lack of investment could cost $17 million over 20 years.

Case Studies Summary

Key Takeaways

- Taking no action for known climate risks is costly; as much as $17.2 million over 20 years (discounted 3.1%) in health, repair, and lost time costs at just one of our study locations
- Lower-cost investments often produce similar or more benefits than higher-cost options
- Return on investment, dollar-for-dollar, for low-cost solutions ranges from 1.5:1 to 6:1, depending on the approach taken and the infrastructure type.
- For all infrastructure types studied, taking similar action across the National Capital Region could lead to significant health savings and avoided costs.

Where do we go from here?

- We now have five indicative case study BCAs regionally that can help make the case for resilience investment not only at those locations, but for similar projects in other locations or at-risk assets around the region
- Framework to help members walk through the process on their own, all five individual models should members like to analyze similar assets
- Helped showcase the importance of BCAs by highlighting the type of information they can provide, can aid with grant applications and board presentations
- Potential to analyze more assets or project examples
- Can help guide other economic analyses / model for other parts of TPB's work program (e.g. safety improvements using a similar approach)

Questions and Comments?

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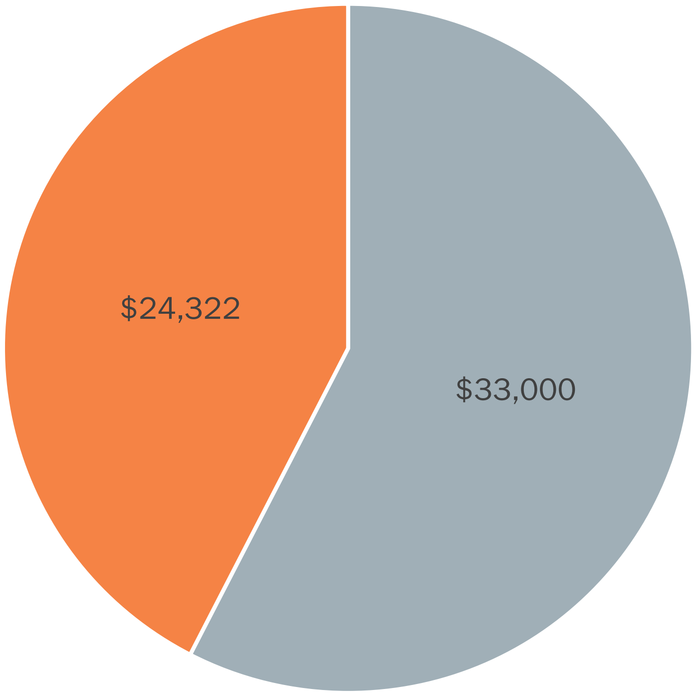
APPENDIX SLIDES

Additional Cost and Benefit Breakdown Charts

Bus Stop Low Cost Approach, Cost Breakdown

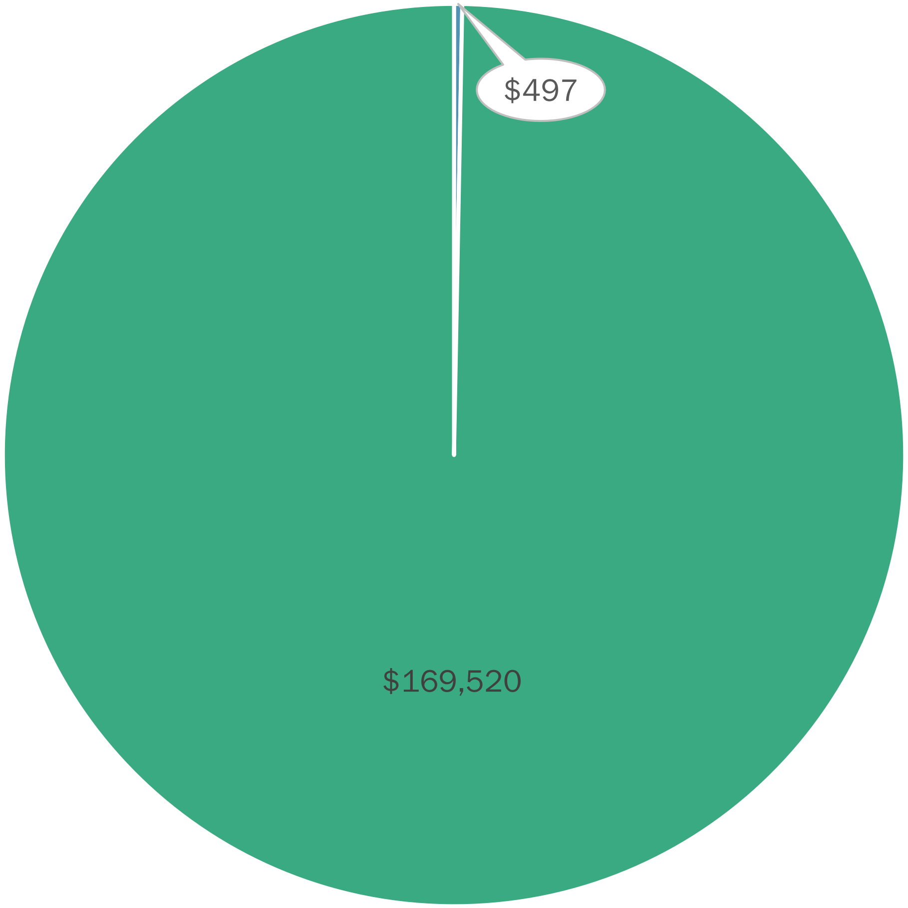


■ Construction Cost ■ Operation Cost

Total Cost Input*: $57,322

**Over 20 years, discounted 3.1%*

Bus Stop Low Cost Approach, Benefits Breakdown

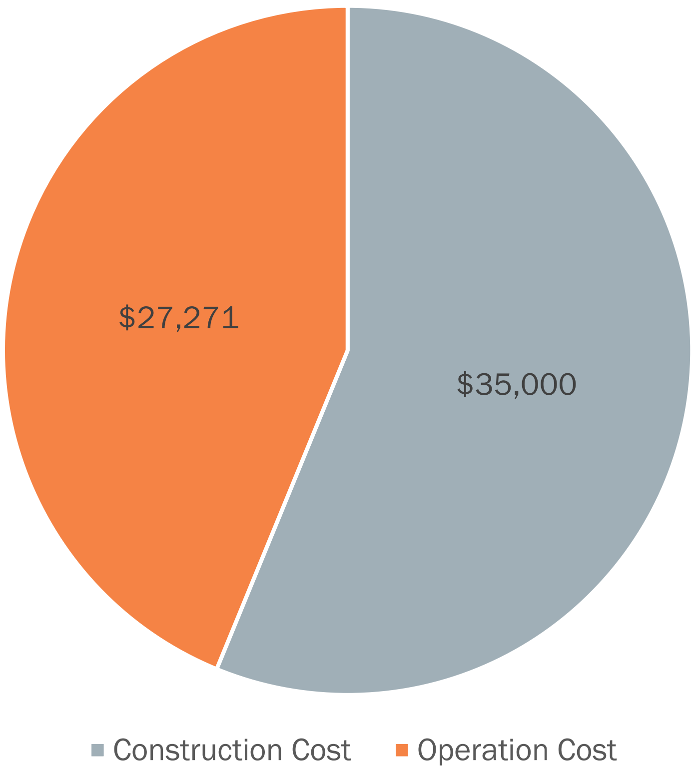


■ Avoided ED Visits & Hospitalizations ■ Advertising Revenue

Total Benefit Output*: $170,017

**Over 20 years, discounted 3.1%*

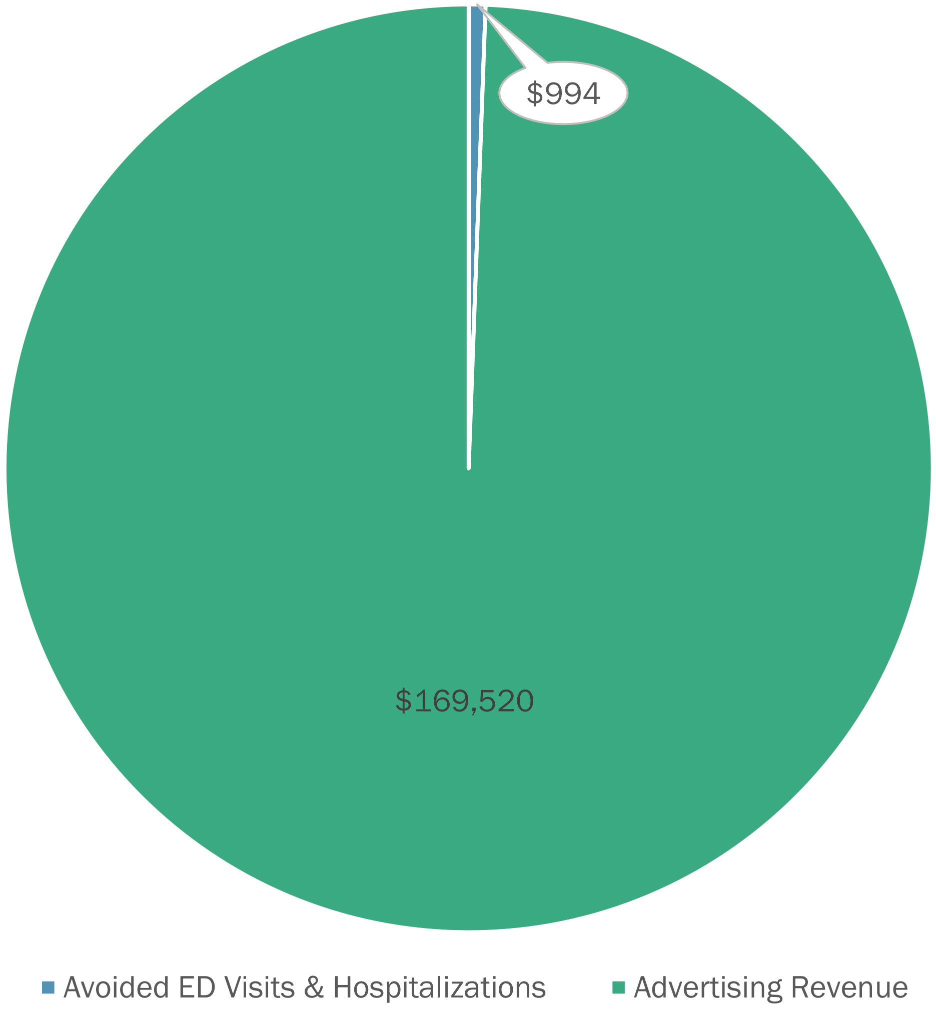
Bus Stop High Cost Approach, Cost Breakdown



Total Cost Input*: $62,271

**Over 20 years, discounted 3.1%*

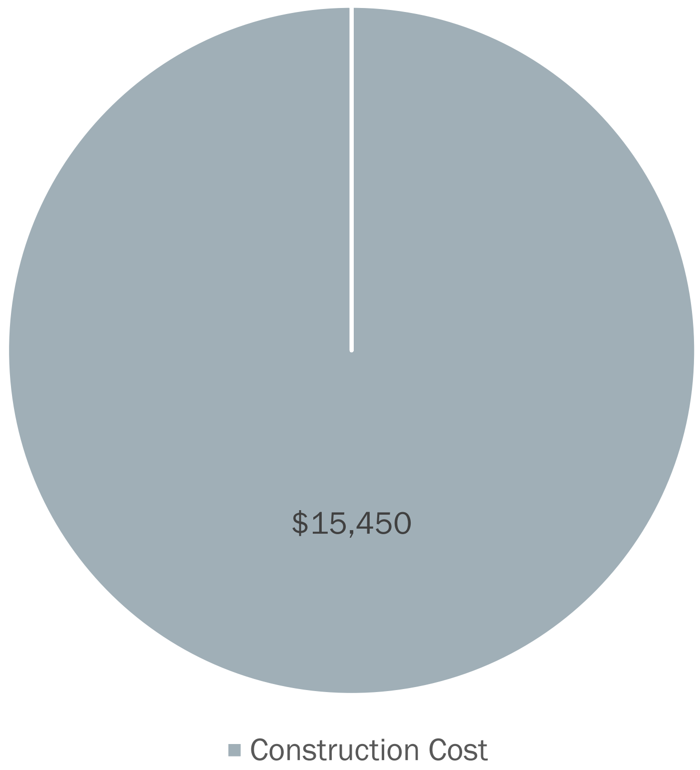
Bus Stop High Cost Approach, Benefits Breakdown



Total Benefit Output*: $170,514

**Over 20 years, discounted 3.1%*

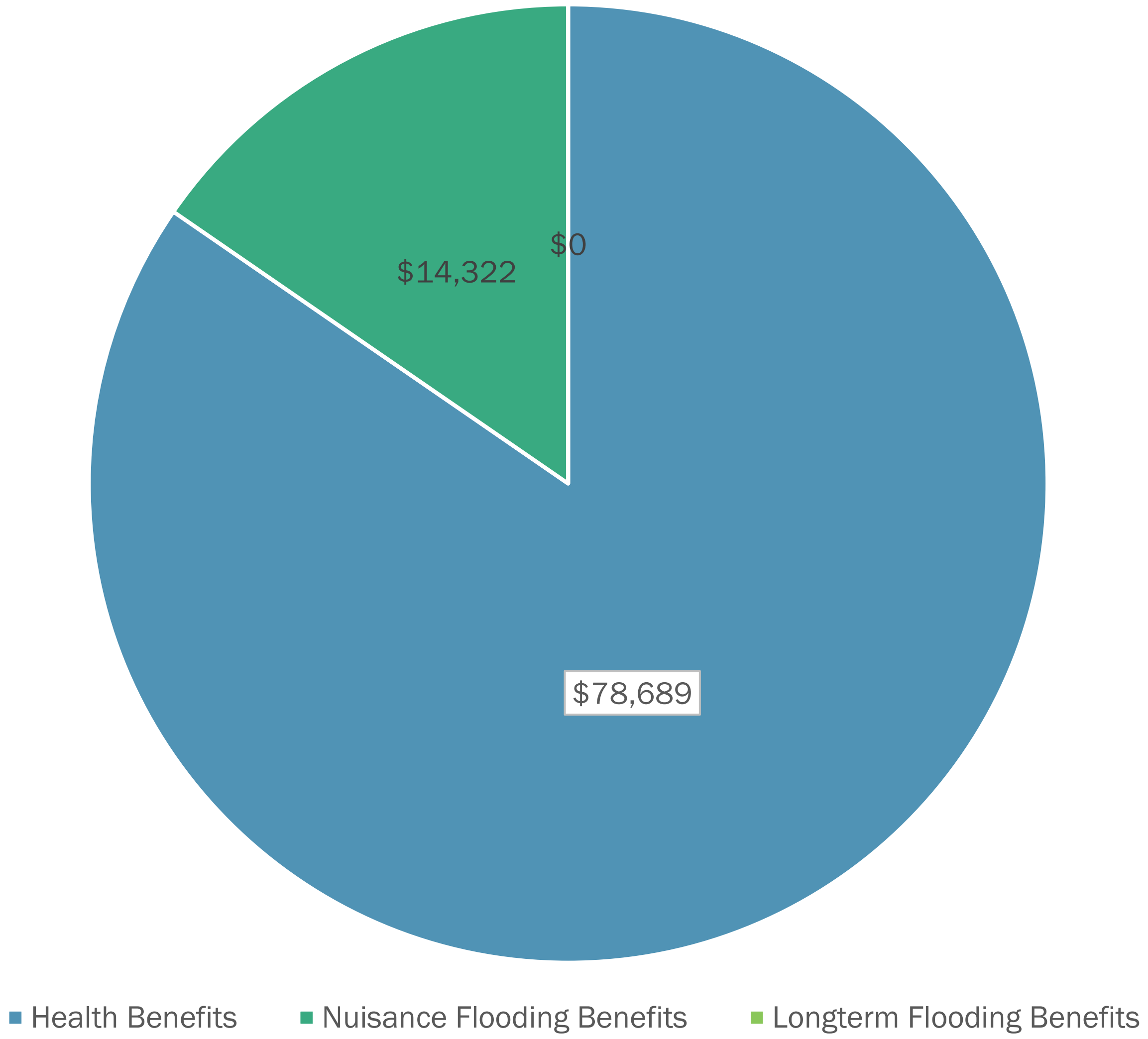
Rail Stop Low Cost Approach, Cost Breakdown



Total Cost Input*: $15,450

**Over 20 years, discounted 3.1%*

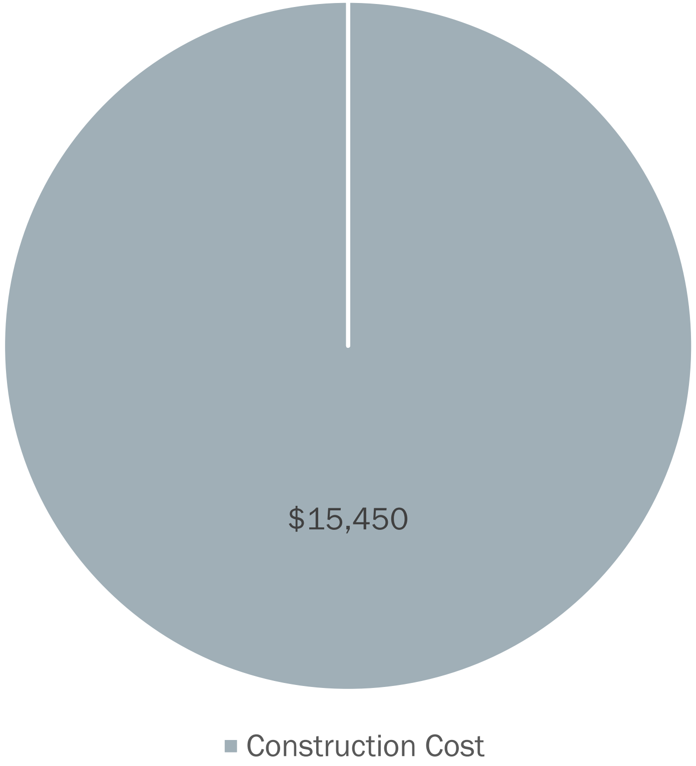
Rail Stop Low Cost Approach, Benefits Breakdown



Total Benefit Output*: $93,012

**Over 20 years, discounted 3.1%*

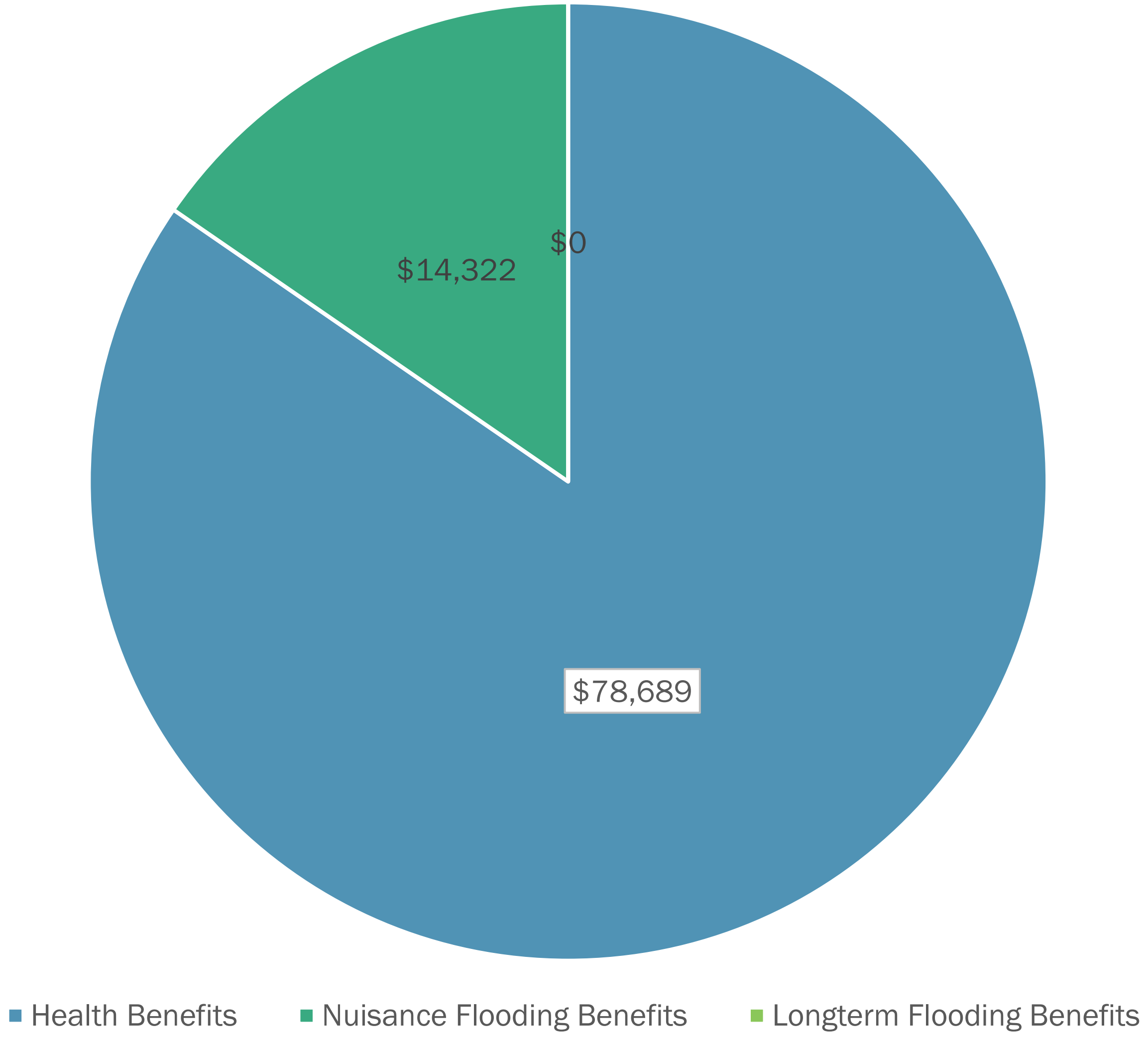
Rail Stop High Cost Approach, Cost Breakdown



Total Cost Input*: $15,450

**Over 20 years, discounted 3.1%*

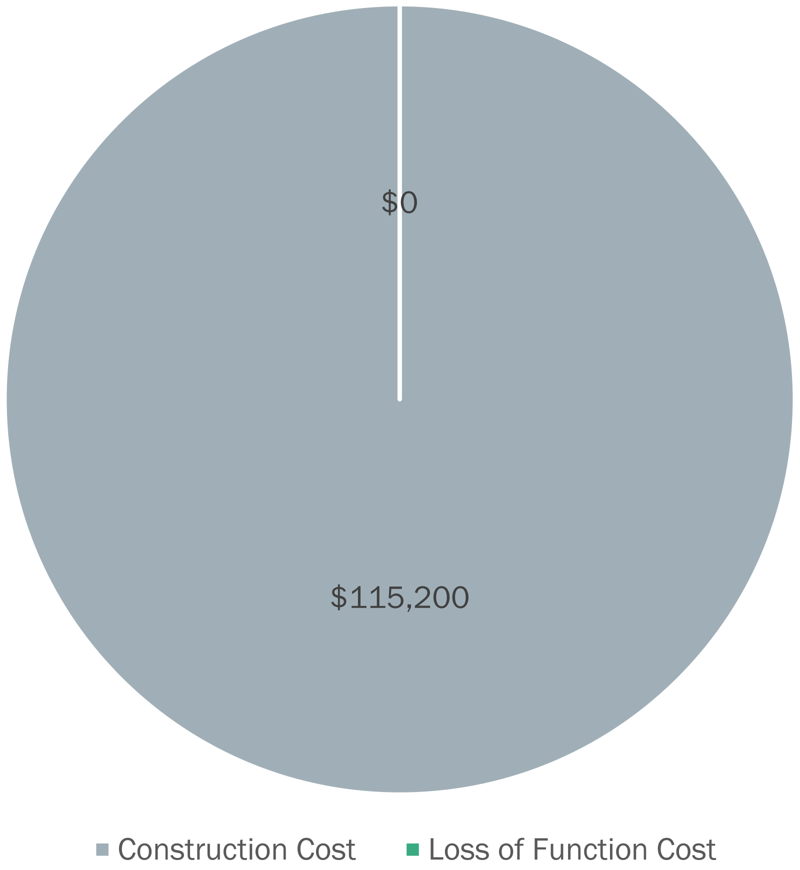
Rail Stop High Cost Approach, Benefits Breakdown



Total Benefit Output*: $93,012

**Over 20 years, discounted 3.1%*

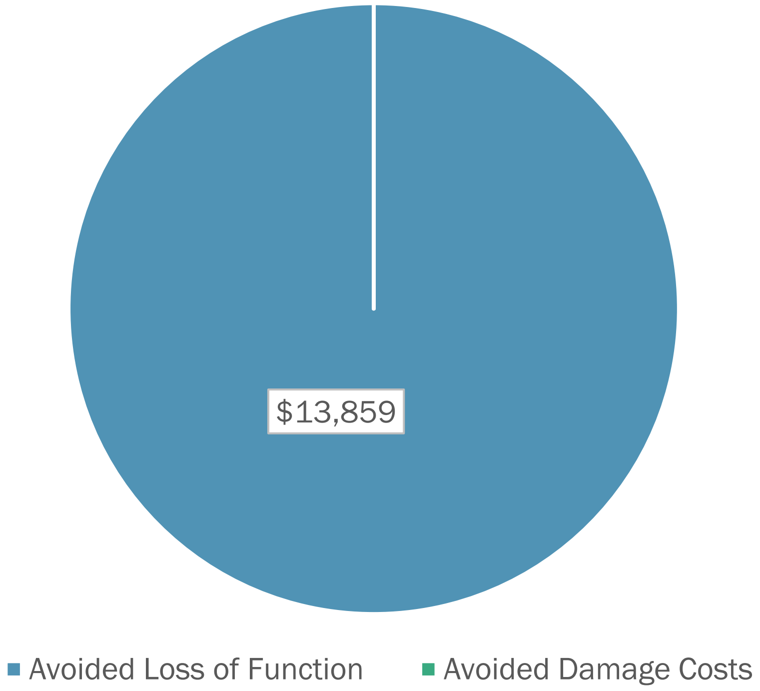
Bridge Low Cost Approach, Cost Breakdown



Total Cost Input*: $115,200

**Over 20 years, discounted 3.1%*

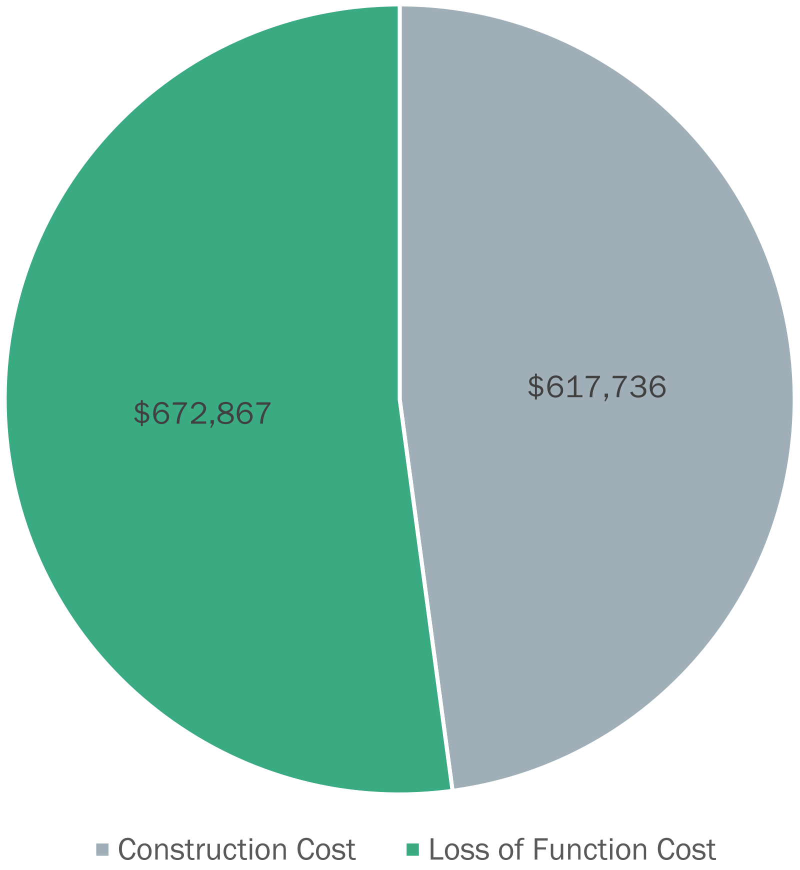
Bridge Low Cost Approach, Benefits Breakdown



Total Benefit Output*: $13,859

**Over 20 years, discounted 3.1%*

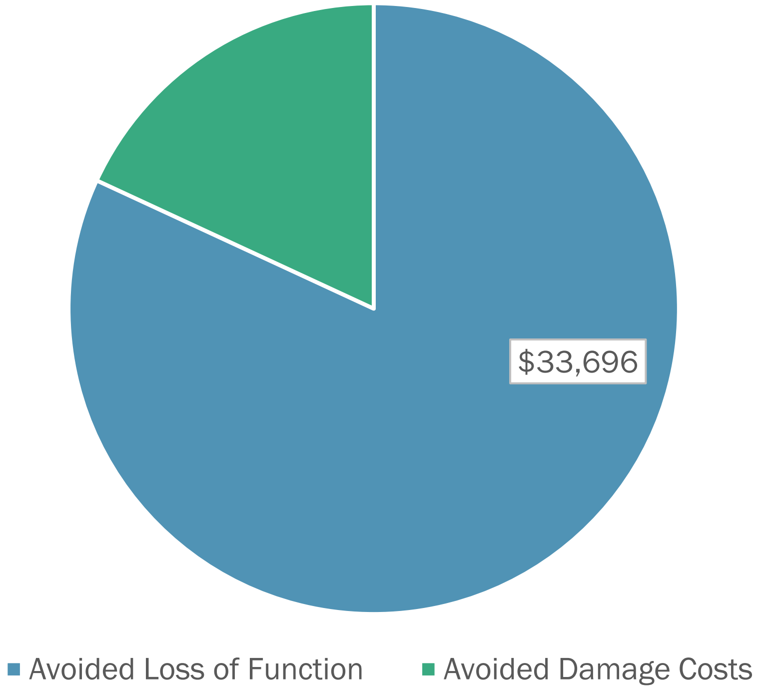
Bridge High Cost Approach, Cost Breakdown



Total Cost Input*: $115,200

Over 20 years, discounted 3.1%

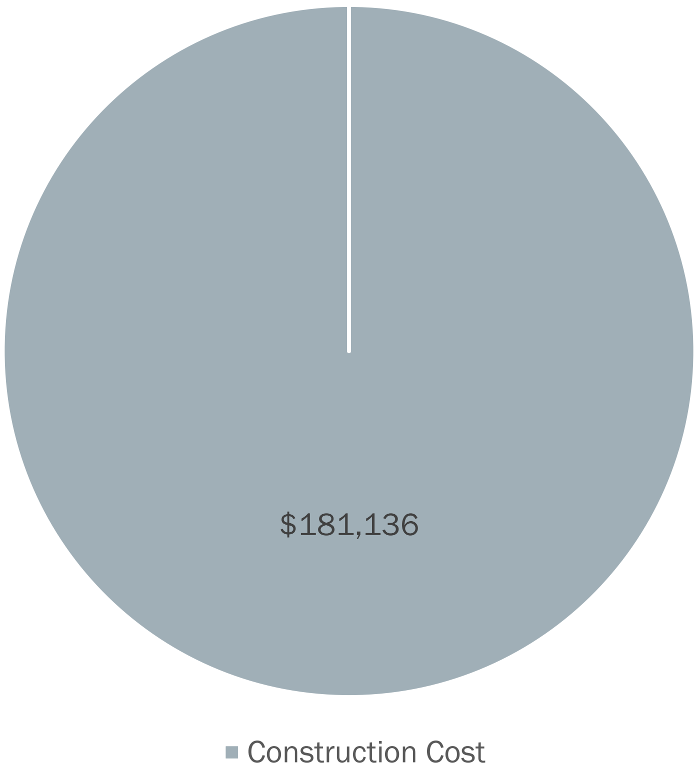
Bridge High Cost Approach, Benefits Breakdown



Total Benefit Output*: $13,859

Over 20 years, discounted 3.1%

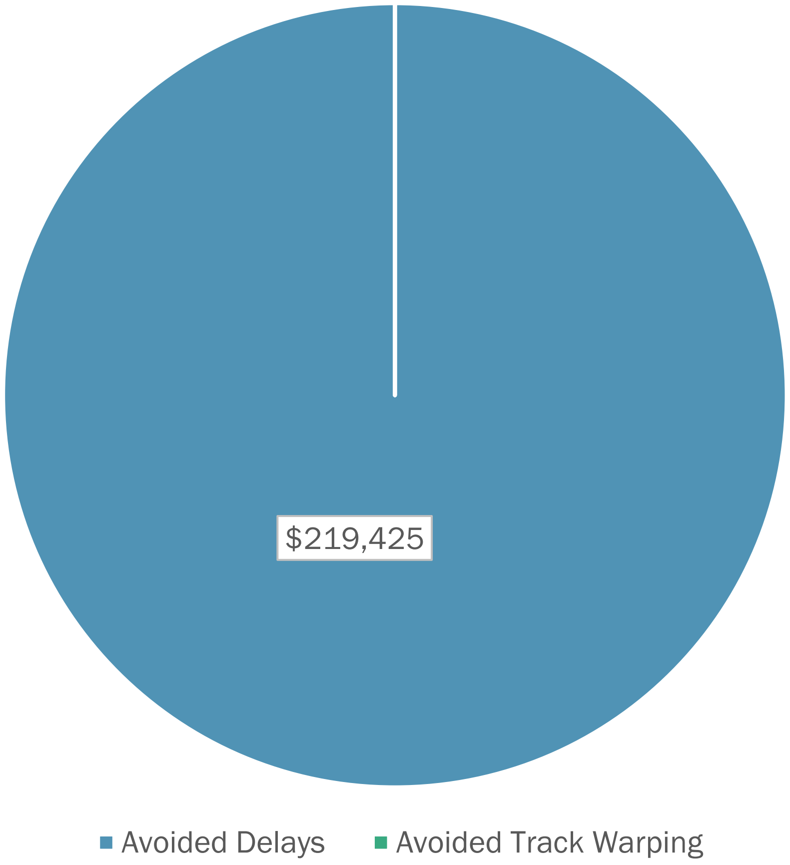
Rail Segment Low Cost Approach, Cost Breakdown



Total Cost Input*: $181,136

**Over 20 years, discounted 3.1%*

Rail Segment Low Cost Approach, Benefits Breakdown



Total Benefit Output*: $219,425

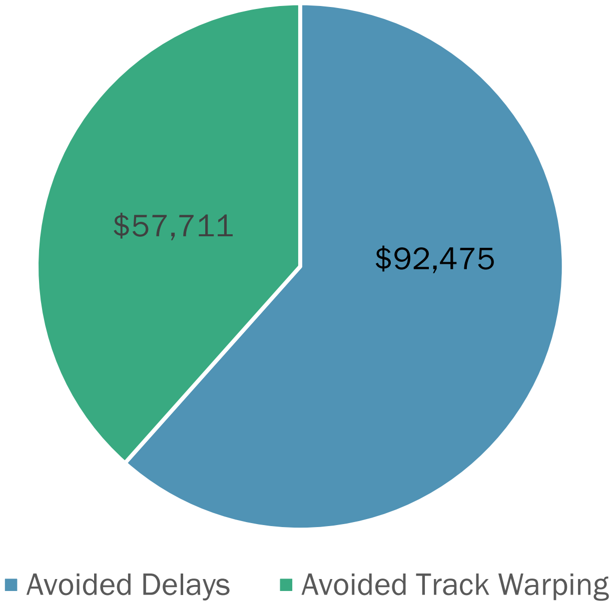
**Over 20 years, discounted 3.1%*

Rail Segment High Cost Approach, Cost Breakdown

Total Cost Input*: $1,130,141

Over 20 years, discounted 3.1%

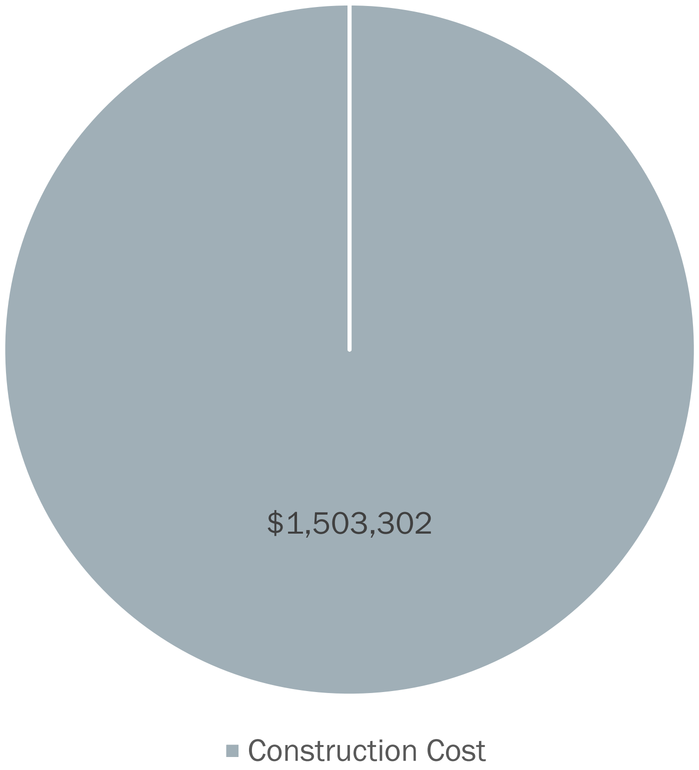
Rail Segment High Cost Approach, Benefits Breakdown



Total Benefit Output*: $150,186

Over 20 years, discounted 3.1%

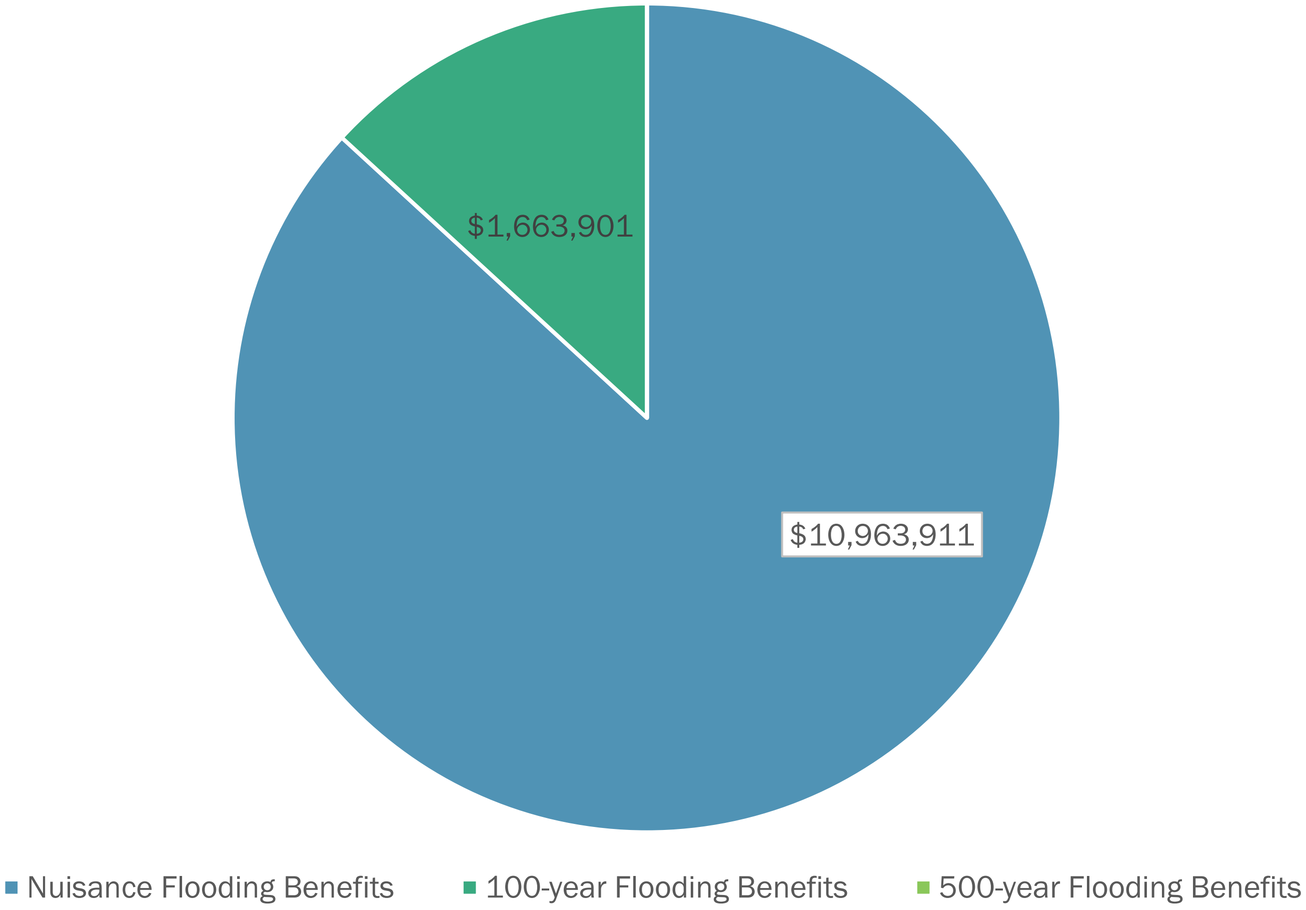
Road Segment Low Cost Approach, Cost Breakdown



Total Cost Input*: $1,503,302

**Over 20 years, discounted 3.1%*

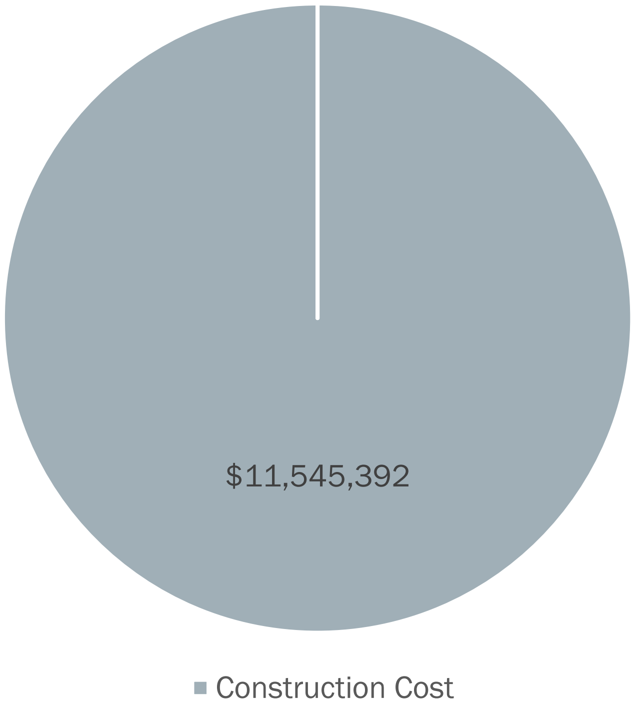
Road Segment Low Cost Approach, Benefits Breakdown



Total Benefit Output*: $12,627,812

**Over 20 years, discounted 3.1%*

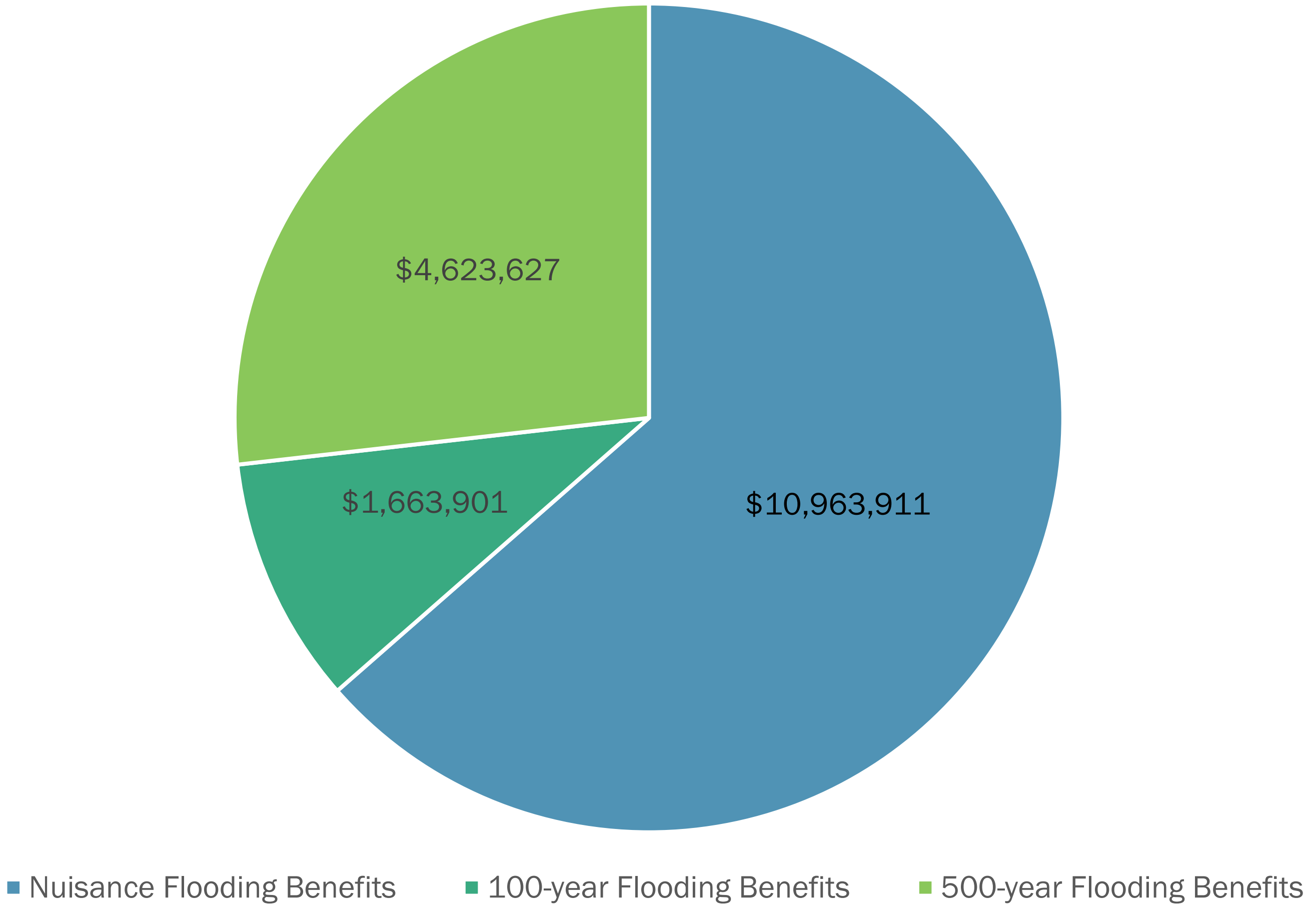
Road Segment High Cost Approach, Cost Breakdown



Total Cost Input*: $11,545,392

**Over 20 years, discounted 3.1%*

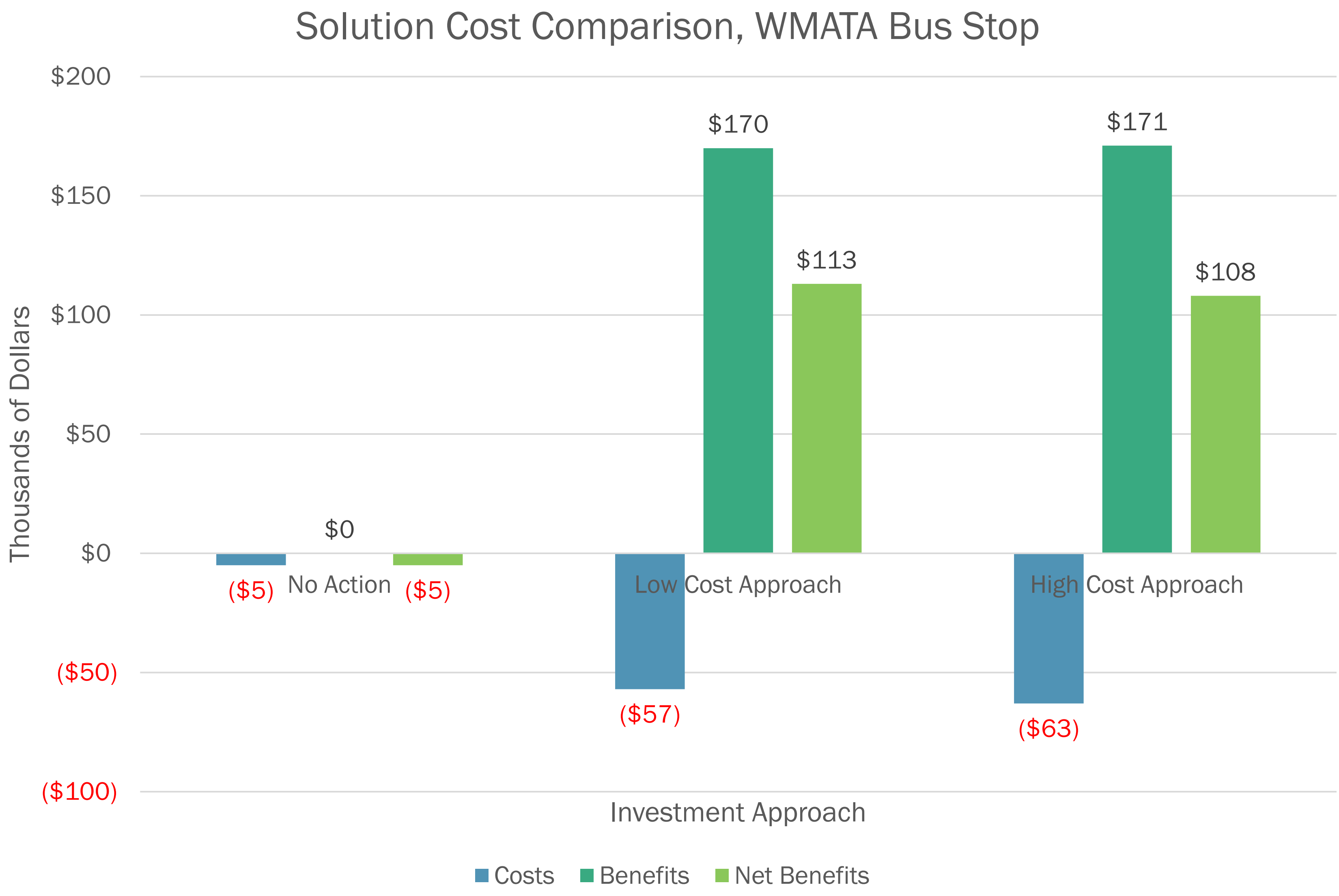
Road Segment High Cost Approach, Benefits Breakdown



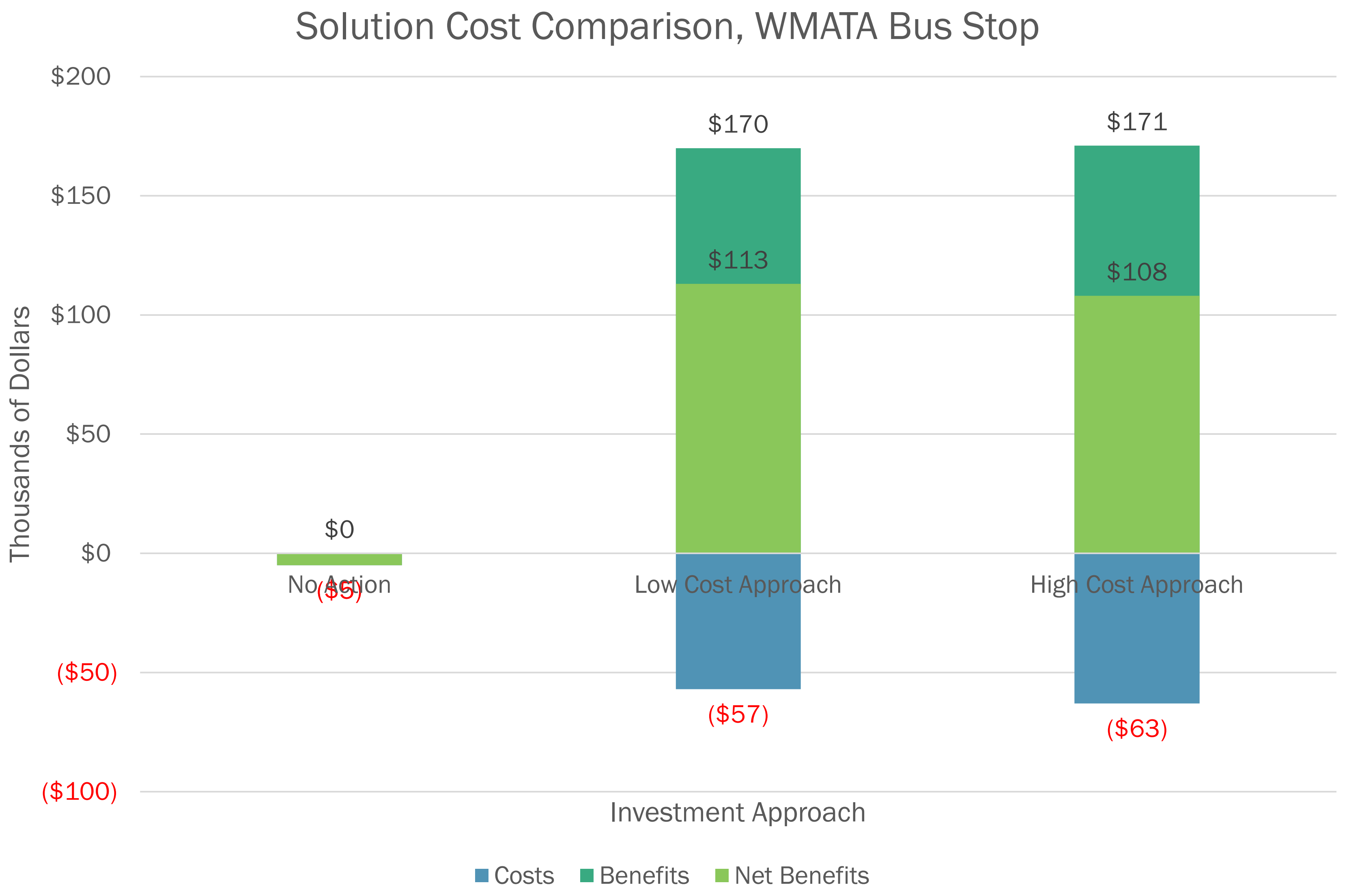
Total Benefit Output*: $17,251,440

**Over 20 years, discounted 3.1%*

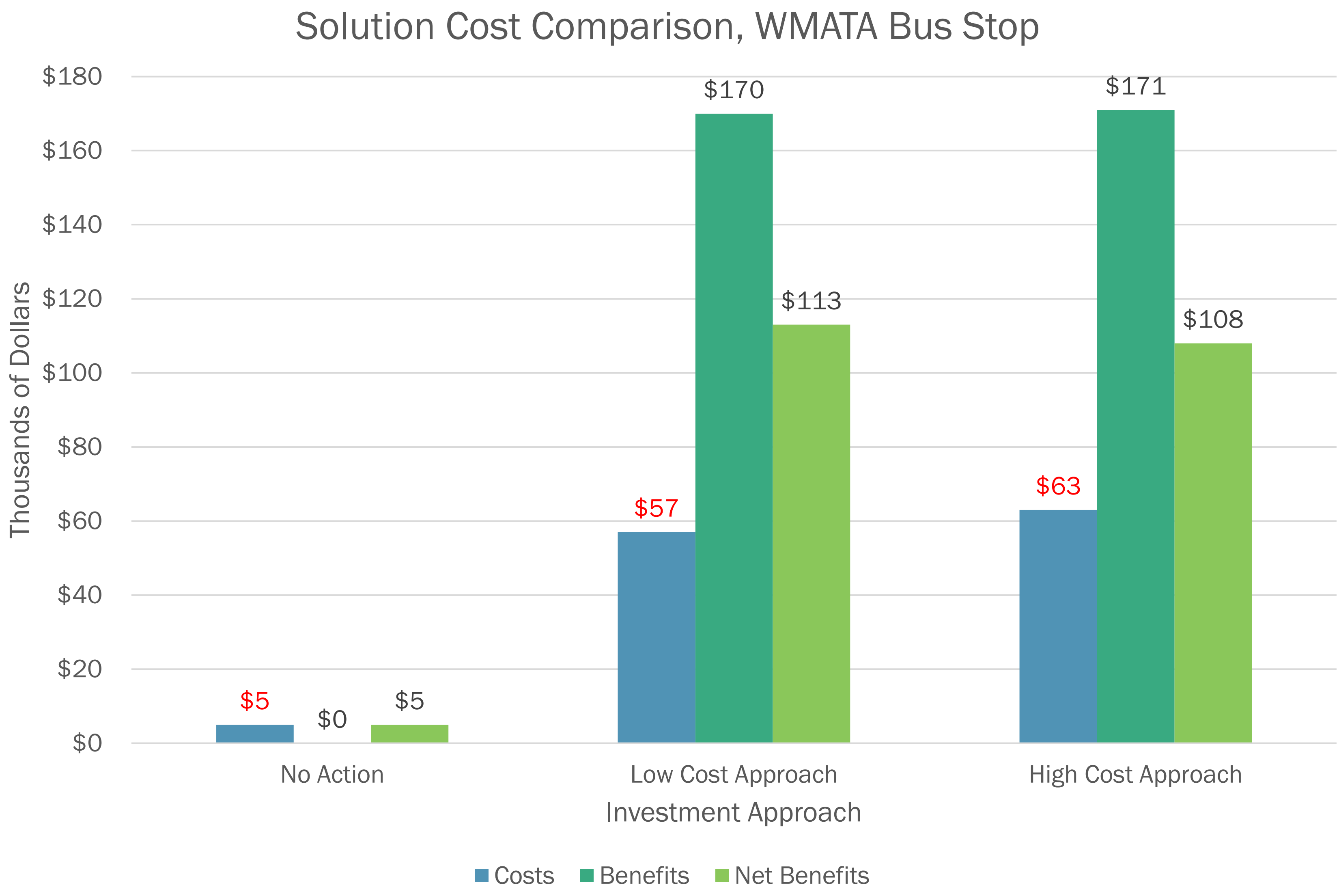
Alternative Visualizations – Bus Stop Cost-Benefit Comparison



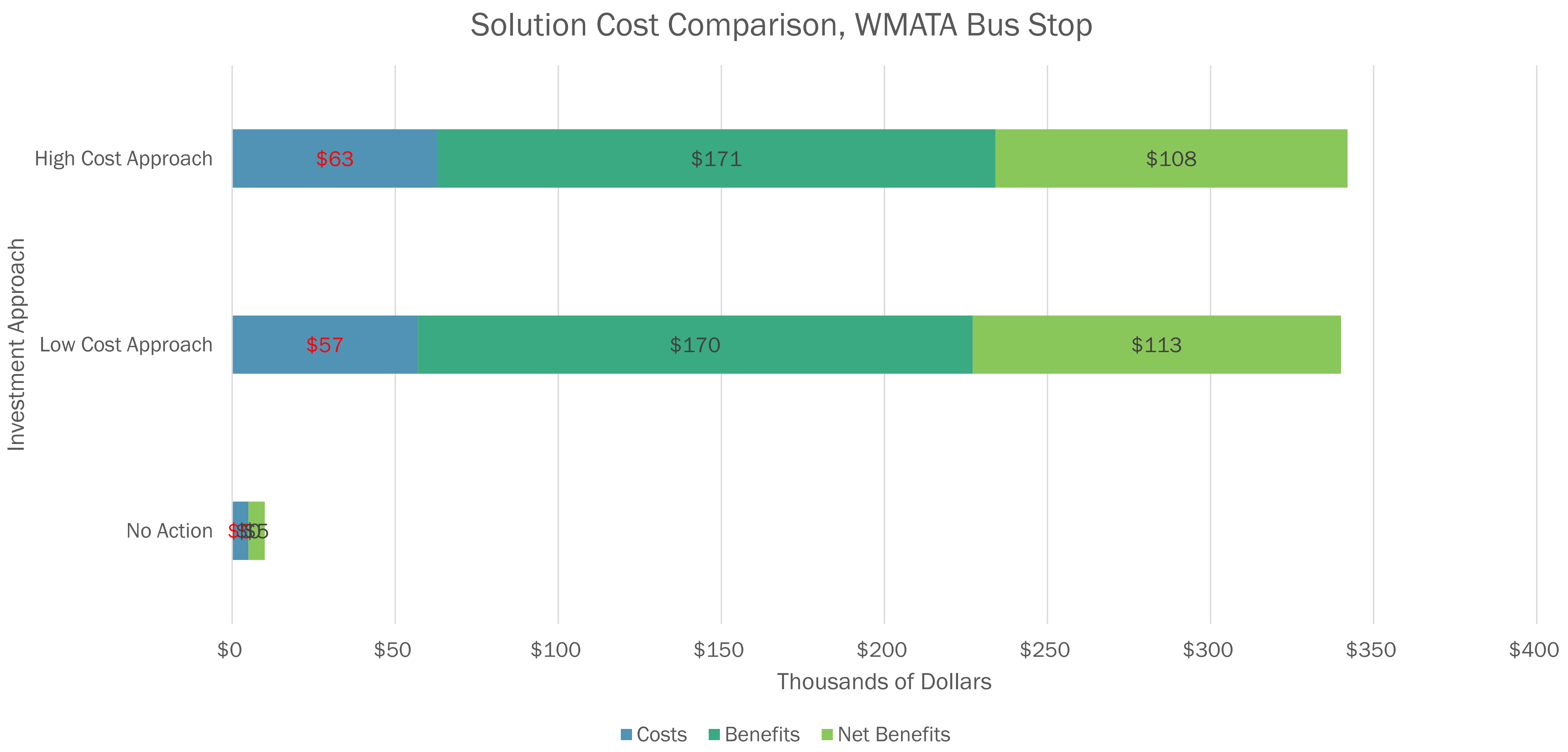
Solution Cost Comparison, WMATA Bus Stop
$200
$150
$100
$50
$0
($50)
($100)
Thousands of Dollars
$170
$171
$113
$108
$0
($5)
No Action
($5)
Low Cost Approach
High Cost Approach
($57)
($63)
Investment Approach
Costs
Benefits
Net Benefits



Solution Cost Comparison, WMATA Bus Stop
$200
$150
$100
$50
$0
($50)
($100)
Thousands of Dollars
$170
$171
$113
$108
$0
($5)
($57)
($63)
No Action
Low Cost Approach
High Cost Approach
Investment Approach
Costs
Benefits
Net Benefits



National Capital Region
Transportation Planning Board



National Capital Region
Transportation Planning Board