Appendix E:
Pennsylvania State Rail Plan Public Benefit Analysis

Passengers boarding SEPTA train at Paoli Station

Source: PennDOT

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Summary

The assessment summarizes public benefits across the freight and passenger rail networks in the Commonwealth of Pennsylvania. Operators on these networks include Class I, II and III freight rail carriers as well as Amtrak passenger rail and Southeastern Pennsylvania Regional Transportation Authority (SEPTA) regional rail services.

Benefits were quantified based on the potential vehicle miles traveled (VMT) that would divert to the road network if the rail network ceased to operate as a result of failure to maintain a minimally acceptable state of repair. Classes of benefits associated with maintaining the rail system include:

- Increased operating costs of automobiles and trucks compared to passenger and freight trains,
- Increased pavement maintenance costs of trucks on roads,
- Increased fatalities and collisions due to travel by automobile and truck compared to rail, and
- Increased emissions due to automobile and truck use compared to trains.

This "avoided VMT" approach thus represents some of the effects of the most extreme outcome of a policy to not implement the projects included in the SRP. For freight, avoided VMT represents an increase of truck-miles based on the diversion of ton-miles carried by rail through 2040. These benefits are calculated for the freight network as a whole and allocated to individual segments based on ton-miles.

For passenger rail, avoided VMT represents an increase of automobile-miles based on the diversion of passenger-miles carried by rail through 2040. These benefits are calculated for individual segments of the passenger rail network based on the passenger-miles that currently use each segment. Benefits are assigned to the following passenger rail network segments in **Table E-1**.

Table E-1: Passenger Rail Network Segments

Amtrak	SEPTA
NEC	Airport Line
Philadelphia-Harrisburg	Chestnut Hill East
Harrisburg-Pittsburgh	Chestnut Hill West
Capitol Limited	Cynwyd
Lake Shore Limited	Lansdale/Doylestown
	Media/Elwyn
	Fox Chase
	Norristown
	Paoli/Thorndale
	Trenton
	Warminster
	Wilmington/Newark
	West Trenton
	SEPTA on NEC
	SEPTA Total Network

Segments are mostly assigned by line for passenger rail. The "SEPTA on NEC" category refers to benefits associated with that portion of SEPTA's network that operates on Amtrak's Northeast Corridor. This includes portions of the Airport Line, Media/Elwyn, Warminster, West Trenton and Wilmington/Newark Lines. The "SEPTA Total Network" represents the benefits of all SEPTA traffic through the trunk line portion of SEPTA's network in Center City Philadelphia as well as the benefits associated with the rest of SEPTA's rail network.

Purpose

The purpose of this assessment is to evaluate the relative benefits created by the passenger and freight rail systems in the Commonwealth of Pennsylvania. The assessment indicates the relative contributions of network segments to the state rail system on a benefits-per-route mile basis. The results of this assessment can be used with other criteria for prioritizing projects.

Approach and Considerations

The analytical approach to this assessment is summarized in this section and described in further detail in the sections that follow.

For passenger rail segments, economic benefits were evaluated based on the assumption that passenger rail trips displace trips that would otherwise be made by private automobile. Individual passenger rail segment benefits were estimated based on the number of rail passenger trips that traverse the segment, and the number of private automobile trips that are avoided as a result of the continued operation of the particular rail segment. For example, a project to enhance capacity or reliability of the core segments of the SEPTA trunk line through Center City Philadelphia would impact all SEPTA Regional Rail trains, and thus all passenger trips that are made on those trains. Likewise, a project in the vicinity of 30th Street station on the Northeast Corridor would impact all Amtrak trains operating on the corridor.

For freight rail projects, economic benefits were evaluated based on the assumption that freight movements across Pennsylvania's rail network displace movements that would otherwise be made by truck. Freight origins and destinations derived from 2013 waybill sample data were assigned to the rail network to estimate ton-miles on each segment of the rail network. Because the waybill sample includes freight shipments beginning in Pennsylvania, ending in Pennsylvania, or moving through Pennsylvania, benefits extend beyond the state line.

As noted in the previous paragraph, isolation of the effects of any individual project is very difficult given the available data, and thus it may be problematic to draw specific conclusions from measures for individual projects. Accordingly, the economic benefits evaluated in this analysis should be understood as a representation of some of the more readily monetizable benefits of the network as a whole. Individual rail projects are likely to have specific safety, capacity, time savings, reliability, economic development, and other benefits that are not quantified in this analysis.

Inputs

The following data were used for the purposes of performing this economic benefits analysis, including data provided by Amtrak, the Pennsylvania Department of Transportation (PennDOT), the Southeastern Pennsylvania Transportation Authority (SEPTA), the Surface Transportation Board (waybill data), and other publicly available sources.

Project List

1. All railroad projects by agency, location, phasing, and estimated cost as compiled for the 2015 Pennsylvania State Rail Plan.

Amtrak Operations Data

2. System wide 2013 passenger-miles, reported by the federal Bureau of Transportation Statistics (BTS).
3. System-wide 2013 operating expenses, as reported in the Amtrak 2013 Annual Report.

4. Total 2014 passenger-miles of trips with an origin or destination in Pennsylvania, by network segment.
5. Total 2014 boardings in Pennsylvania, by route and station.
6. Forecasted boardings by route and station in Pennsylvania for years 2019 and 2035.
7. Total 2013 nationwide boardings and average trip lengths by line, as reported by the National Association of Railroad Passengers (NARP).
8. Total electricity and diesel fuel consumption, as reported in the 2013 Amtrak Sustainability Report.
9. Total metric tons of carbon dioxide, volatile organic compounds, nitrogen oxides, particulate matter (diesel only), and sulfur dioxide emissions, as reported in the 2013 Amtrak Sustainability Report.

SEPTA Operations Data

10. Total 2013 system-wide boardings by line and station, regional rail network, as provided in the FY 2013 SEPTA Annual Service Operating Plan.
11. Average passenger trip length, regional rail network, as provided in the SEPTA Strategic Plan document.
12. Total system-wide operating expenses, regional rail network, as reported by SEPTA to the National Transit Database (NTD).
13. SEPTA Regional Rail ridership numbers and forecasts, by line in five year increments, for the years 2010 through 2040, as prepared by the Delaware Valley Regional Planning Commission (DVRPC).
14. Total electricity consumption, as reported by SEPTA to the NTD.

Freight Operations Data

15. Surface Transportation Board waybill data for 2013 for interstate and intrastate freight traffic in Pennsylvania, including total tonnage, total distance, total number of shipments, by commodity type.
16. Annual ton-miles of freight moved, by mode, U.S. total, as reported by BTS.
17. Annual ton-miles moved and operating expenses for Class I railroads, as published by the Association of American Railroads (AAR) for the year 2014.
18. Total truck payload capacity by truck type, as estimated by the Federal Highway Administration's (FHWA) *Comprehensive Truck Size and Weight Study*.

Economic, Safety, Emissions, and Monetization Factors

19. Average automobile occupancy rate for Pennsylvania, as published by the National Center for Transit Research at the University of South Florida.
20. Average per-mile automobile operating cost, as published by the American Automobile Association (AAA) for the year 2013.
21. Average per-mile truck operating costs by cost category (fuel, lease-purchase agreements,

maintenance, insurance, etc.), as published by the American Transportation Research Institute (ATRI) for the year 2014.

22. Average marginal cost of pavement deterioration per truck-mile, as reported in the 2000 Addendum to the 1997 *Federal Highway Cost Allocation Study*.
23. Average crash rates, injury rates, and fatality rates per vehicle-mile of travel for automobiles, as reported by BTS for the year 2014.
24. Total truck-involved crashes, injuries, and fatalities for truck-involved crashes, as reported by the National Highway Traffic Safety Administration (NHTSA) for the year 2013.
25. Amtrak, SEPTA, total national train crashes, injuries, fatalities, and value of property damage as reported by the Federal Railroad Administration (FRA) for the year 2013.
26. Value of fatalities, injuries, and property damage resulting from automobile crashes, as indicated by the U.S. Department of Transportation's *TIGER Benefit-Cost Analysis Resource Guide*, in 2013 dollars.
27. Per-mile passenger car emission rates for carbon dioxide and particulate matter as reported by the Environmental Protection Agency (EPA).
28. Per-mile passenger car emission rates for volatile organic compounds and nitrogen oxides as reported by the BTS.
29. Per-mile truck and rail emission rates for carbon dioxide, volatile organic compounds, nitrogen oxides, and particulate patter as reported by the EPA.
30. Total rates of carbon dioxide, nitrogen oxides, particulate matter, and sulfur dioxide emissions per megawatt-hour of electricity generated in Pennsylvania, as reported by the U.S. Energy Information Administration (EIA).
31. Value of reduced emissions of carbon dioxide, volatile organic compounds, nitrogen oxides, particulate matter, and sulfur dioxide, as provided in the TIGER Benefit-Cost Analysis Resource Guide, in 2013 dollars.

Analysis Methodology and Results

Separate methodologies were developed for evaluating the economic benefits of the passenger rail and freight rail systems in Pennsylvania. This was primarily a function of the available data, the extent and complexity of the respective systems, and the nature of the benefits imparted.

For both the freight and passenger rail systems, network benefits are computed using a spreadsheet-based benefits model using the inputs described above. After evaluating benefits over a 25-year time horizon, the model then summarizes the present value of benefits. Discount rates of both three percent and seven percent are tested in the model, which is consistent with the approach required for TIGER benefit-cost analyses.

Passenger Rail Network Benefits

Passenger rail network benefits are estimated based on total Amtrak and SEPTA ridership, by segment. The estimate of benefits was based upon the assertion that, in the absence of the passenger rail network, trips would otherwise be made by private automobile, which would result in increased user operating costs, emissions, and crashes.

SEPTA PASSENGER-MILES FORECAST

Total annual system-wide SEPTA passenger-miles were broken out by branch and by mainline segment in proportion to the relative number of boardings on each branch, as provided by SEPTA. Annual passenger-miles were estimated based on forecasted growth in boardings by line. The branch estimates were then summed to arrive at a total estimate of ridership along the downtown core of the system and on the lines which operate over Amtrak's Northeast Corridor. Accordingly, trunk segments that carry traffic to and from multiple branches have higher passenger-miles. **Table E-2** summarizes the resulting estimate of current and future passenger-miles by SEPTA branch.

Table E-2: Estimated Annual SEPTA Passenger Miles of Travel (millions), 2015 – 2040

Segment	2015 Estimated	2020 Forecast	2040 Forecast
Airport Line	26.3	26.5	27.8
Chestnut Hill East	21.9	22.2	23.4
Chestnut Hill West	20.4	20.6	20.9
Cynwyd	2.3	2.4	2.6
Lansdale/Doylestown	65.6	66.6	71.5
Media/Elwyn	41.4	42.1	44.4
Fox Chase	19.9	19.9	20.4
Norristown	41.2	42.0	45.0
Paoli/Thorndale	85.7	87.6	93.9
Trenton	45.5	45.6	47.4
Warminster	34.8	35.3	37.6
Wilmington/Newark	36.5	36.6	37.1
West Trenton	48.5	48.7	50.9
SEPTA on NEC	**187.4**	**189.2**	**197.8**
SEPTA Total Network	**490.0**	**496.1**	**522.9**

AMTRAK PASSENGER-MILES FORECAST

The Amtrak passenger rail network in Pennsylvania was divided into five operating segments for the purposes of ridership and passenger-mile estimation:

- Northeast Corridor (NEC)
- Philadelphia-Harrisburg
- Harrisburg-Pittsburgh
- Capitol Limited
- Lake Shore Limited

Each segment includes all passenger miles originating in or destined for Pennsylvania. Amtrak data does not, however, include passenger miles for through trips that neither begin nor end in Pennsylvania.

Existing and forecasted ridership, by station, was provided by Amtrak, as well as existing total passenger-miles associated with boardings at each station. Future year passenger-miles of Amtrak travel on Pennsylvania routes were estimated based on the boardings forecast. Theforecastwassummarizedaccordingtothefive operating segments described above. **Table E-3** summarizes the resulting passenger-miles forecast.

Table E-3: Estimated Amtrak Passenger Miles of Travel (millions) for Trips Originating and/or Ending in Pennsylvania, 2015 – 2040

Segment	2015 Estimated	2020 Forecast	2040 Forecast
NEC	516.2	557.7	703.9
Philadelphia-Harrisburg	149.5	167.0	232.7
Harrisburg-Pittsburgh	71.8	80.8	115.2
Capitol Limited	1.4	1.6	2.1
Lake Shore Limited	7.6	8.3	11.0

VEHICLE-MILES OF TRAVEL DIVERTED FORECAST

As noted above, it was assumed that all trips made on rail represent trips that would otherwise be made by private automobile. It was assumed that each passenger-mile by rail displaces the same number of passenger-miles that would otherwise have been made by car. This simplifying assumption ignores potential changes in total trip length between the two modes of travel, due to the lack of data for estimating automobile trip lengths. To convert passenger-miles to vehicle-miles of travel (VMT), passenger-miles were divided an occupancy factor of 1.07 persons per private automobile.[1] For Amtrak, passenger miles are counted for all trips originating or ending within Pennsylvania. Through trips are not counted.

BENEFIT: MODE SHIFT AUTOMOBILE OPERATING COST SAVINGS

To convert the estimated reduction in private automobile VMT to operating cost savings, a vehicle operating cost of $0.69 per mile was assumed, based on the American Automobile Association's *Your Driving Costs* report, adjusted to 2015 dollars. Total cost savings were then reduced by the estimated cost of operating Amtrak and SEPTA services for the respective lines.

Total estimated VMT reduction, and the net cost savings attributable to the shift to rail, are summarized in **Table E-4.** Cost savings are expressed in 2015 dollars.

1 National Center for Transit Research, University of South Florida. "State Averages for Private Vehicle Occupancy, Carpool Size, and Vehicles per 100 Workers", Pennsylvania average vehicle occupancy (AVO) value. Values derived from 2000 Census data. Available at www.nctr.usf.edu/clearinghouse/censusavo.htm.

Table E-4: Estimated Reduction In Vehicle Miles Traveled (In Millions) and Corresponding Savings in Operating Costs (in Millions Of 2015 Dollars) Due to Passenger Rail in Pennsylvania

Segment	2015 Estimated		2020 Forecast		2040 Forecast	
	VMT Savings	Cost Savings	VMT Savings	Cost Savings	VMT Savings	Cost Savings
Amtrak						
NEC	482.4	$15.26	521.2	$16.48	657.8	$20.80
Philadelphia-Harrisburg	139.7	$4.42	156.1	$4.94	217.5	$6.88
Harrisburg-Pittsburgh	67.1	$2.12	75.5	$2.39	107.7	$3.41
Capitol Limited	1.3	$0.04	1.5	$0.05	1.9	$0.06
Lake Shore Limited	7.1	$0.22	7.8	$0.25	10.3	$0.32
Amtrak Total	**697.6**	**$22.06**	**762.1**	**$24.11**	**995.2**	**$31.47**
SEPTA						
Airport Line	24.5	$4.09	24.8	$4.13	26.0	$4.33
Chestnut Hill East	20.4	$3.40	20.7	$3.45	21.9	$3.64
Chestnut Hill West	19.1	$3.18	19.3	$3.21	19.5	$3.25
Cynwyd	2.2	$0.37	2.3	$0.38	2.5	$0.41
Lansdale/Doylestown	61.3	$10.21	62.2	$10.36	66.8	$11.13
Media/Elwyn	38.7	$6.44	39.3	$6.54	41.5	$6.91
Fox Chase	18.6	$3.10	18.6	$3.10	19.0	$3.17
Norristown	38.5	$6.42	39.2	$6.53	42.1	$7.01
Paoli/Thorndale	80.1	$13.33	81.9	$13.63	87.8	$14.62
Trenton	42.5	$7.08	42.6	$7.10	44.3	$7.38
Warminster	32.5	$5.41	33.0	$5.50	35.2	$5.85
Wilmington/Newark	34.1	$5.67	34.2	$5.69	34.7	$5.78
West Trenton	45.3	$7.55	45.5	$7.58	47.5	$7.91
SEPTA on NEC	**175.1**	**$29.16**	**176.8**	**$29.44**	**184.9**	**$30.78**
SEPTA Total Network	**457.8**	**$76.25**	**463.6**	**$77.20**	**488.8**	**$81.39**

BENEFIT: COLLISION REDUCTION

Travel by rail instead of private automobile is also expected to result in fewer crashes per passenger mile, resulting in a reduction in fatalities, injuries, and property damage. As with the previous benefit, collision cost savings were estimated based on the assumption that all trips made on passenger rail would otherwise have been made using private automobiles in the absence of the rail network. The same railroad passenger-mile and private automobile VMT estimates shown in **Tables E-2, E-3**, and **E-4** were used for this benefit calculation as well.

Rates of automobile crashes, fatalities, and injuries, as well as the average cost of property damage per crash, were based on data published by the BTS for the year 2013. Amtrak and SEPTA crash, fatality,

and injury rates were based on data reported to the FRA for the year 2013. The average property damage associated with train crashes was based on BTS data for the year 2013. All train crash statistics were assumed to correlate to passenger-miles. This simplifying assumption reflected the dearth of available data by network segment and implies that the relationship between train-miles and passenger-miles would remain relatively consistent.

To estimate the overall collision cost savings benefit, the total number of crashes, fatalities, and injuries on each mode were estimated for the same overall trip demand, with the difference between the rail and automobile modes constituting the benefit.

To monetize the value of net lives saved, net injuries avoided, and automobile property damage avoided, monetization factors were taken from the 2015 TIGER Cost-Benefit Analysis Resource Guide. The estimated property damage costs associated with the corresponding increase in train crashes were based on the average property damage costs associated with train crashes as reported by the BTS. The results of the analysis are summarized in **Table E-5**. Cost savings are expressed in 2015 dollars.

Table E-5: Passenger Rail Collision Reduction Impact (in millions of 2015 dollars)

Segment	2015 Forecast			2020 Forecast			2040 Forecast		
	Auto Collision Costs Avoided	Increased Rail Collision Costs	Net Cost Savings	Auto Collision Costs Avoided	Increased Rail Collision Costs	Net Cost Savings	Auto Collision Costs Avoided	Increased Rail Collision Costs	Net Cost Savings
Amtrak									
NEC	$216.4	$135.4	**$81.0**	$233.8	$146.3	**$87.5**	$295.1	$184.7	**$110.4**
Philadelphia-Harrisburg	$62.7	$39.2	**$23.5**	$70.0	$43.8	**$26.2**	$97.6	$61.0	**$36.6**
Harrisburg-Pittsburgh	$30.1	$18.8	**$11.3**	$33.9	$21.2	**$12.7**	$48.3	$30.2	**$18.1**
Capitol Limited	$0.6	$0.4	**$0.2**	$0.7	$0.4	**$0.3**	$0.9	$0.5	**$0.4**
Lake Shore Limited	$3.2	$2.0	**$1.2**	$3.5	$2.2	**$1.3**	$4.6	$2.9	**$1.7**
Amtrak Total	**$313.0**	**$195.8**	**$117.2**	**$341.9**	**$213.9**	**$128.0**	**$446.5**	**$279.3**	**$167.2**

Table E-5: Passenger Rail Collision Reduction Impact (in millions of 2015 dollars), cont.

SEPTA									
Airport Line	$11.0	$7.8	**$3.2**	$11.1	$7.9	**$3.2**	$11.7	$8.3	**$3.4**
Chestnut Hill East	$9.2	$6.5	**$2.7**	$9.3	$6.6	**$2.7**	$9.8	$7.0	**$2.8**
Chestnut Hill West	$8.6	$6.1	**$2.5**	$8.6	$6.1	**$2.5**	$8.8	$6.2	**$2.6**
Cynwyd	$1.0	$0.7	**$0.3**	$1.0	$0.7	**$0.3**	$1.1	$0.8	**$0.3**
Lansdale/ Doylestown	$27.5	$19.6	**$7.9**	$27.9	$19.9	**$8.0**	$30.0	$21.3	**$8.7**
Media/Elwyn	$17.3	$12.3	**$5.0**	$17.6	$12.5	**$5.1**	$18.6	$13.2	**$5.4**
Fox Chase	$8.4	$5.9	**$2.5**	$8.4	$5.9	**$2.5**	$8.5	$6.1	**$2.4**
Norristown	$17.3	$12.3	**$5.0**	$17.6	$12.5	**$5.1**	$18.9	$13.4	**$5.5**
Paoli/Thorndale	$35.9	$25.6	**$10.3**	$36.7	$26.1	**$10.6**	$39.4	$28.0	**$11.4**
Trenton	$19.1	$13.6	**$5.5**	$19.1	$13.6	**$5.5**	$19.9	$14.1	**$5.8**
Warminster	$14.6	$10.4	**$4.2**	$14.8	$10.5	**$4.3**	$15.8	$11.2	**$4.6**
Wilmington/Newark	$15.3	$10.9	**$4.4**	$15.3	$10.9	**$4.4**	$15.6	$11.1	**$4.5**
West Trenton	$20.3	$14.5	**$5.8**	$20.4	$14.5	**$5.9**	$21.3	$15.2	**$6.1**
SEPTA on NEC	**$78.5**	**$55.9**	**$22.7**	**$79.2**	**$56.3**	**$22.9**	**$83.0**	**$59.3**	**$23.9**
SEPTA Total Network	**$205.5**	**$146.2**	**$59.3**	**$207.8**	**$147.7**	**$60.1**	**$219.4**	**$155.9**	**$63.5**

BENEFIT: EMISSIONS REDUCTION

Travel by rail instead of private automobile also generally results in lower per-mile emissions. The approach to monetizing this impact closely follows the approach used for operating costs and collision costs. The pollutants measured include carbon dioxide (CO_2), volatile organic compounds (VOCs), nitrogen oxides (NOx), particulate matter (PM), and sulfur dioxide (SO_2).

Emission rates for private automobiles were estimated based on data provided by the BTS (for VOC and NOx emissions) and by the EPA (for CO2 and VOCs). Data was available for particulate matter, but only for Amtrak diesel operations.

Emission rates for Amtrak were estimated separately for diesel and electric propulsion. For diesel service, Amtrak's nationwide total emissions, as reported in the agency's *Sustainability Report*, were converted to per-passenger-mile rates based on total national passenger-miles carried on diesel lines. The per-passenger-mile rates of diesel emissions were then used to calculate total emissions attributable to the three non-electrified Amtrak segments. For electric service, Amtrak's total electricity consumption was converted to a per-passenger-mile rate for the company's electric lines, which was converted to emissions rates based on per-megawatt-hour emission rates for electric generation in the northeastern United States, as reported by the EIA.

Emission rates for SEPTA, which operate only electric service, were calculated based on total electricity consumption for SEPTA Regional Rail service, as reported to the National Transit Database, converted to a per-passenger-mile rate.

Per-passenger-mile electricity consumption data were converted to total emissions based on the same EIA electric generation emissions data described in the previous paragraph.

The resulting net change in emissions was monetized based on recommended factors included in the *2015 TIGER Cost-Benefit Analysis Resource Guide*. The results are summarized in **Table E-6**.

As shown, there is a moderate negative benefit associated with Amtrak's diesel operations in Pennsylvania, which suggests that trains on these lines currently have higher passenger mile traveled (PMT) emissions than PMT in private automobiles. The monetized net per mile emissions penalty of diesel passenger rail operations is just $0.04 in 2015 and is estimated to decrease to $0.035 in 2040. No adjustments were made to reflect potential improvements in emissions rates over time with new locomotives or changes in propulsion method.

Table E-6: Passenger Rail Emissions Reduction Impact (in millions of 2015 dollars)

Segment	Propulsion	2015 Forecast	2020 Forecast	2040 Forecast
Amtrak				
NEC	Electric	$9.15	$10.65	$17.53
Philadelphia-Harrisburg	Electric	$2.65	$3.19	$5.79
Harrisburg-Pittsburgh	Diesel	-$2.80	-$3.09	-$4.06
Capitol Limited	Diesel	-$0.06	-$0.06	-$0.07
Lake Shore Limited	Diesel	-$0.30	-$0.32	-$0.39
Amtrak Total		**$8.64**	**$10.37**	**$18.80**
SEPTA				
Airport Line	Electric	$0.19	$0.22	$0.34
Chestnut Hill East	Electric	$0.16	$0.18	$0.28
Chestnut Hill West	Electric	$0.15	$0.17	$0.25
Cynwyd	Electric	$0.02	$0.02	$0.03
Lansdale/Doylestown	Electric	$0.48	$0.55	$0.87
Media/Elwyn	Electric	$0.30	$0.35	$0.54
Fox Chase	Electric	$0.15	$0.16	$0.25
Norristown	Electric	$0.30	$0.34	$0.55
Paoli/Thorndale	Electric	$0.62	$0.72	$1.14
Trenton	Electric	$0.33	$0.37	$0.57
Warminster	Electric	$0.25	$0.29	$0.46
Wilmington/Newark	Electric	$0.27	$0.30	$0.45
West Trenton	Electric	$0.35	$0.40	$0.62
SEPTA on NEC	Electric	$1.36	$1.55	$2.40
SEPTA Total Network		**$3.57**	**$4.07**	**$6.35**

Freight Rail Network Benefits

Freight rail network benefits are estimated based on the total tonnage of freight moved through Pennsylvania by rail. The estimate of benefits was based upon the assertion that, in the absence of the freight rail system, freight would otherwise be moved by truck, which would result in increased shipping costs, pavement maintenance costs, emissions, and crashes. Benefits are limited to operations on railroad segments within the state.

FREIGHT TON-MILES FORECAST

Total freight tonnage moved through Pennsylvania by rail was derived from a 2013 sample of carload waybill data published by the Surface Transportation Board. Ton-miles of freight were derived from the waybill by calculating the product of distance, shipments and the billed weight in tons, and the sample expansion factor to reflect the estimated universe of freight trips. Ton-miles were summarized by Standard Transportation Commodity Code. The estimated ton-miles include not only the distance traveled within Pennsylvania, but the total distance of the shipment, provided that at least part of the journey was within Pennsylvania.

Waybill data on freight origins and destinations was also used to estimate the tonnage on each segment of the rail network. Shipments were assigned to the rail network using least-impedance algorithms in travel demand modeling software. The tonnage assigned to each segment was multiplied by segment length to compute ton-miles by segment. A conversion factor was applied to reconcile differences in paths through the network between the observations in the waybill data and the model's assignment.

To estimate the future growth in freight shipments, past national growth in nationwide rail freight tonnage was analyzed. Using BTS data covering a 31-year period from 1980 through 2011, an average annual growth rate of 2.8 percent per year was calculated. This was applied to the Pennsylvania waybill-derived ton-miles data to develop a forecast through the year 2040 and is summarized in **Table E-7**.

Table E-7: Estimated Ton-Miles (millions) of Freight, Intrastate and Interstate Movements Through Pennsylvania

Commodity	2015	2020	2040
Hazardous Materials	38,734	44,501	77,528
Coal	25,039	28,767	50,117
Misc. Mixed Shipments	20,400	23,437	40,831
Food or Kindred Products	17,930	20,599	35,887
Shipping Containers	13,524	15,538	27,069
Chemicals or Allied Products	11,793	13,549	23,605
Pulp, Paper, or Allied Products	9,555	10,978	19,125
Primary Metal Products	6,838	7,856	13,686
Waste or Scrap Materials	6,575	7,553	13,159
Nonmetallic Minerals	6,438	7,396	12,885

Table E-7: Estimated Ton-Miles (millions) of Freight, Intrastate and Interstate Movements Through Pennsylvania, cont.

Commodity	2015	2020	2040
Farm Products	4,992	5,735	9,991
Transportation Equipment	4,870	5,595	9,747
Lumber or Wood Products	4,671	5,367	9,350
Clay, Concrete, Glass or Stone	3,765	4,325	7,536
Petroleum or Coal Products	3,274	3,761	6,552
Apparel or Related Products	1,562	1,794	3,126
Metallic Ores	1,119	1,285	2,239
Waste Nonflammable Compressed Gases	894	1,028	1,790
Crude Petrol or Natural Gas	740	851	1,482
Rubber or Misc. Plastics	549	631	1,099
Electrical Equipment	479	550	958
Furniture or Fixtures	403	463	806
Machinery	355	408	711
Misc. Manufacturing Products	327	375	654
Fabricated Metal Products	326	374	652
Printed Matter	208	239	417
Small Packaged Freight Shipments	178	205	357
Misc. Freight Shipments	149	171	298
Freight Forwarder Traffic	95	110	191
Textile Mill Products	64	73	128
Fresh Fish or Marine Products	31	36	62
Instruments, Photo & Optical Equipment	28	32	56
Leather or Leather Products	11	12	21
Ordinance or Accessories	10	12	21
Mail or Contract Traffic	10	11	19
Forest Products	5	6	10
TOTAL	**185,941**	**213,623**	**372,165**

FREIGHT TRUCK-MILES DIVERTED FORECAST

Each of the four benefits associated with freight rail are based on the use of rail instead of truck that is made possible by the freight system as it currently exists. To estimate the truck-mile equivalents of freight rail tonnage carried in and through Pennsylvania, truck payload capacities were used, as published by the U.S. Department of Transportation's 2000 *Comprehensive Truck Size and Weight Study*. The payload capacities, by truck type, are summarized in **Table E-8**.

Table E-8: Assumed Truck Payload Capacities

Truck Type	Payload Capacity (Pounds)
Platform/Flatbed	30,715
Van	34,890
Grain Body	48,970
Dump Truck	34,760
Tank Body	47,980

As with the automobile VMT calculations, a simplifying assumption was made that a freight journey by rail would cover the same number of miles as the equivalent movement in a truck. The payload factors above were therefore used to convert the ton-miles forecast to a forecast of the equivalent truck-miles that would be added to the roadway network in the absence of Pennsylvania's freight rail network. These results are summarized in **Table E-9**.

Table E-9: Estimated Truck-Miles (millions) of Freight, Intrastate and Interstate Movements Through Pennsylvania

Commodity	Truck Type	2015	2020	2040
Hazardous Materials	Tank Body	1,614.60	1,854.97	3,231.67
Coal	Dump Truck	1,440.70	1,655.18	2,883.61
Misc. Mixed Shipments	Van	1,169.39	1,343.48	2,340.58
Food or Kindred Products	Van	1,027.79	1,180.80	2,057.15
Shipping Containers	Platform/Flatbed	880.63	1,011.73	1,762.61
Pulp, Paper, or Allied Products	Van	547.73	629.28	1,096.31
Chemicals or Allied Products	Tank Body	491.59	564.78	983.94
Primary Metal Products	Platform/Flatbed	445.23	511.52	891.15
Waste or Scrap Materials	Dump Truck	378.29	434.61	757.16
Transportation Equipment	Platform/Flatbed	317.08	364.29	634.66
Lumber or Wood Products	Platform/Flatbed	304.16	349.44	608.79
Nonmetallic Minerals	Grain Body	262.92	302.06	526.24

Table E-9: Estimated Truck-Miles (millions) of Freight, Intrastate and Interstate Movements Through Pennsylvania, cont.

Commodity	Truck Type	2015	2020	2040
Clay, Concrete, Glass or Stone	Dump Truck	216.62	248.87	433.57
Farm Products	Grain Body	203.87	234.23	408.06
Petroleum or Coal Products	Tank Body	136.46	156.78	273.13
Apparel or Related Products	Van	89.52	102.84	179.17
Metallic Ores	Dump Truck	64.36	73.94	128.82
Waste Nonflammable Compressed Gases	Tank Body	37.28	42.83	74.62
Rubber or Misc. Plastics	Van	31.48	36.17	63.02
Crude Petrol or Natural Gas	Tank Body	30.86	35.46	61.77
Electrical Equipment	Van	27.43	31.52	54.91
Machinery	Platform/Flatbed	23.12	26.56	46.27
Furniture or Fixtures	Van	23.09	26.52	46.21
Misc. Manufacturing Products	Platform/Flatbed	21.28	24.45	42.59
Fabricated Metal Products	Platform/Flatbed	21.21	24.37	42.46
Printed Matter	Van	11.95	13.73	23.92
Small Packaged Freight Shipments	Van	10.21	11.73	20.44
Misc. Freight Shipments	Van	8.52	9.79	17.06
Freight Forwarder Traffic	Van	5.47	6.28	10.94
Textile Mill Products	Van	3.66	4.20	7.33
Fresh Fish or Marine Products	Van	1.77	2.04	3.55
Instruments, Photo & Optical Equipment	Van	1.62	1.86	3.23
Leather or Leather Products	Van	0.61	0.70	1.22
Ordinance or Accessories	Van	0.59	0.68	1.18
Mail or Contract Traffic	Van	0.55	0.63	1.09
Forest Products	Platform/Flatbed	0.32	0.37	0.65
TOTAL		**9,851.96**	**11,318.69**	**19,719.08**

BENEFIT: MODE SHIFT SHIPPER COST SAVINGS

The benefits of rail service to shippers were estimated by comparing the difference in average per-mile shipping costs by rail and by truck. Average per-mile truck shipping costs were based on data published by the American Transportation Research Institute in September 2014. The total cost of $1.79 per truck-mile (in 2015 dollars) includes fuel, lease/purchase costs, repairs, maintenance, insurance, driver wages and benefits, and other miscellaneous costs.

Rail operations and maintenance costs were estimated on a per-ton-mile basis based on nationwide ton-mile and gross operating cost data for Class I railroads, as reported by the Association of American Railroads in May 2015. The estimated rail operations and maintenance (O&M) cost is $0.29 per ton-mile, in 2015 dollars.

Total annual truck-miles and ton-miles were calculated by the respective unit operating costs for the modes to produce a comparison of the relative cost of each mode. Subtracting rail costs for truck costs yielded the net operating cost savings of using rail as compared with trucking. The net operating cost savings is summarized in **Table E-10**.

Table E-10: Mode Shift Shipper Cost Savings (in millions of 2015 dollars)

	2015 Forecast	2020 Forecast	2040 Forecast
Total truck miles	9,852	11,319	19,719
Total truck operating cost	$17,611	$20,233	$35,250
Total rail ton-miles	185,939	213,621	372,164
Total rail operating cost	$5,435	$6,244	$10,877
Net shipper cost savings	**$12,176**	**$13,989**	**$24,373**

BENEFIT: PAVEMENT MAINTENANCE COST SAVINGS

Pavement maintenance costs were estimated based on the avoided diversion of rail shipments to trucks supported by Pennsylvania's freight rail network. Whereas the shipper cost savings reflect benefits that would accrue to private shippers and cascade through the economy, pavement maintenance cost savings reflect benefits to the public, because rail O&M costs include the cost of maintaining the tracks, while truck operating costs do not include the cost of maintaining highways.

The cost of pavement deterioration associated with trucks was estimated at $0.127 per truck-mile for typical 5-axle 80-kip trucks, in 2000 dollars. This figure was derived from the 2000 Addendum to the 1997 *Federal Highway Cost Allocation Study Final Report.* Adjusted to 2015 dollars, this equates to a cost of $0.169 per truck-mile. Based on this unit cost, the annual pavement maintenance cost savings are summarized in **Table E-11**.

Table E-11: Pavement Maintenance Cost Savings (in millions of 2015 dollars)

	2015 Forecast	2020 Forecast	2040 Forecast
Total truck miles	9,852	11,319	19,719
Net pavement maintenance cost savings	**$1,660**	**$1,907**	**$3,323**

BENEFIT: COLLISION REDUCTION

Truck collision, injury, and fatality rates were computed on a per-truck-mile basis using national data on total truck crash statistics reported by National Highway Traffic Safety Administration (NHTSA) for the year 2013. Rail collision, injury, and fatality rates were calculated on a per-ton-mile basis using similar nationwide data published by BTS for the year 2013.

The economic costs of fatalities and injuries are based on the 2015 TIGER Cost-Benefit Analysis Resource Guide. The costs of property damage resulting from truck crashes is also from the 2015 *TIGER Cost-Benefit Analysis Resource Guide*, while the cost of property damage resulting from train crashes was based on BTS data on average train crash property damage costs.

The net benefit of collision cost savings for freight was based on the total collision costs associated with trucking, minus the total costs associated with moving the same freight by rail. The net benefits are summarized in **Table E-12.**

Table E-12: Freight Collision Reduction Impact (dollar values in millions of 2015 dollars)

	2015 Forecast	2020 Forecast	2040 Forecast
Total truck miles (millions)	9,852	11,319	19,719
Total truck collisions	12,251	14,075	24,522
Total rail ton-miles (millions)	185,939	213,621	372,164
Total train collisions	196	225	392
Net reduction in fatalities	64	73	128
Net reduction in injuries	1,681	1,931	3,364
Net reduction in property damage (millions)	$15.5	$17.8	$31.0
Net collision reduction impact (millions)	**$1.4**	**$1.6**	**$2.7**

BENEFIT: EMISSIONS REDUCTION

Emission rates for trucks were estimated using per-truck-mile emission factors for CO2, VOCs, NOx, and PM, as provided by the EPA. SO2 emissions factors were unavailable for trucks, and were omitted from this analysis.

Rail emission rates were published by the EPA on a grams per-brake horsepower-hour basis, which were then converted to grams per gallon of diesel based on another EPA fuel energy intensity factor. The emissions factors were converted from grams per gallon to grams per ton-mile based on an assumed factor of 434 metric ton-miles of freight per gallon of diesel, as published by the Texas Transportation Institute. Results are shown in **Table E-13.**

Table E-13: Freight Emissions Reductions Impact (in millions of miles and 2015 dollars)

	2015 Forecast	2020 Forecast	2040 Forecast
Total truck miles	9,852	11,319	19,719
Total truck emissions cost	$2,323	$2,771	$5,573
Total rail ton-miles	185,939	213,621	372,164
Total rail emissions cost	$1,198	$1,399	$2,607
Net emissions reduction impact	**$1,125**	**$1,372**	**$2,966**

Summary of Findings

A total of seven benefit classes were presented in the previous section; three for passenger rail and four for freight rail.

Analysis is performed for two time horizons: a short five-year time horizon between 2015 and 2019 and a long-term 20-year time horizon from 2020 through 2040. The net present value of benefits was computed using both a three percent and a seven percent discount rate, which is consistent with TIGER benefit-cost analysis guidelines, for both time horizons. **Table E-14** summarizes the passenger rail benefits through 2040.

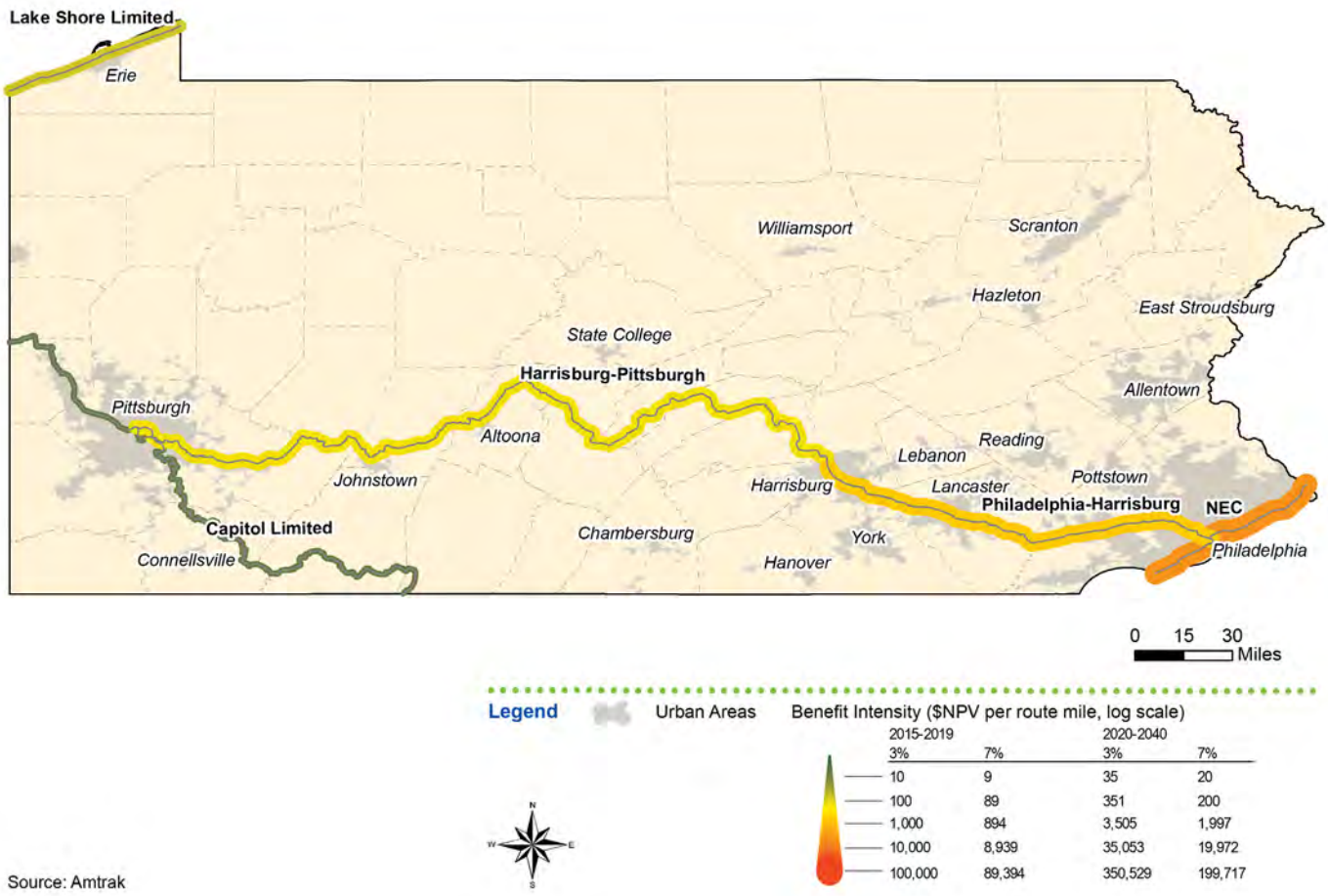
Table E-14: Summary of Passenger Rail Benefits through 2040 (in millions of 2015 dollars)

	NPV 3%		NPV 7%	
	2015-2019	2020-2040	2015-2019	2020-2040
Amtrak – Composite				
Operating cost savings	$105	$362	$94	$207
Collision reduction	$557	$1,922	$498	$1,097
Emissions reduction	$43	$183	$38	$102
Total	**$705**	**$2,467**	**$630**	**$1,406**
SEPTA Total Network				
Operating cost savings	$351	$1,050	$314	$608
Collision reduction	$273	$816	$244	$473
Emissions reduction	$17	$67	$15	$38
Total	**$641**	**$1,933**	**$573**	**$1,119**

Benefits are assigned to Amtrak based on five segments: the Northeast Corridor, Capitol Limited, Lake Shore Limited, Keystone and Pennsylvanian services to Harrisburg, and Pennsylvanian Service between Harrisburg and Pittsburgh. Using a total benefit per route mile, **Figures E-1** and **E-2** have mapped these benefits for Amtrak and SEPTA at a net present value of three percent and seven percent.

For Amtrak, the largest benefits per mile occur on the Northeast Corridor, which represents over one-third of Amtrak's system ridership. Significant benefits can also be found on the Keystone East Corridor between Philadelphia and Harrisburg.

Figure E-1: Amtrak Benefits per Segment Route Mile for Trips With an Origin and/or Destination in Pennsylvania



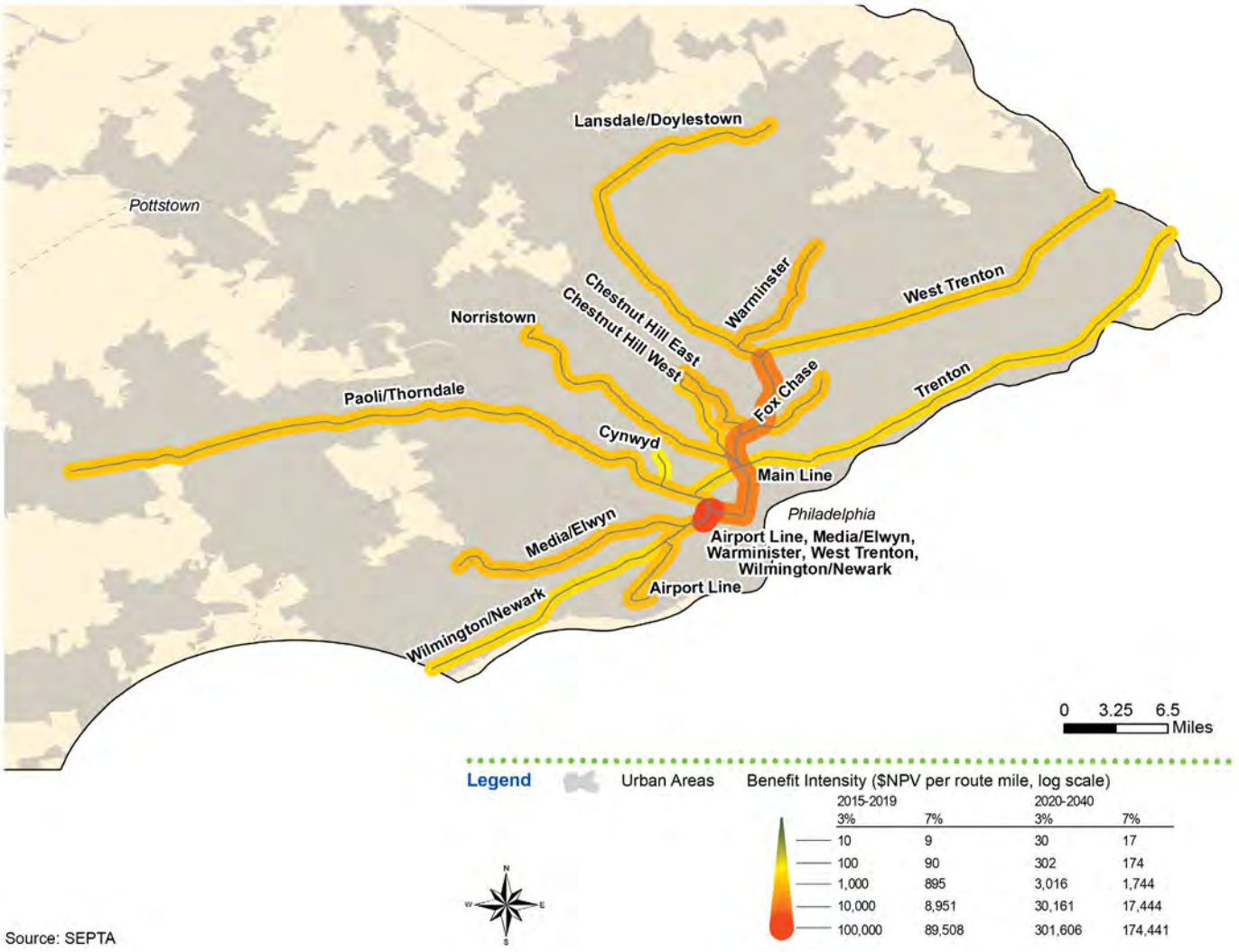
Source: Amtrak

All of SEPTA's 13 commuter rail lines operate along some portion of the system's Trunk Line (the segment between Philadelphia's 30th Street Station and Jenkintown-Wyncote, where several northern commuter rail lines branch off) and, thus, improvements on this segment support benefit gains system-wide.

Significant benefits also accrue on a segment between University City and 30th Street Station. Here, three different SEPTA commuter rail lines operate on a pair of tracks owned by SEPTA.

Elsewhere, benefits are fairly evenly distributed along most of SEPTA's Regional Rail lines, with smaller benefit gains on the Chestnut Hill West and Cynwyd Lines.

Figure E-2: SEPTA Benefits per Segment Route Mile



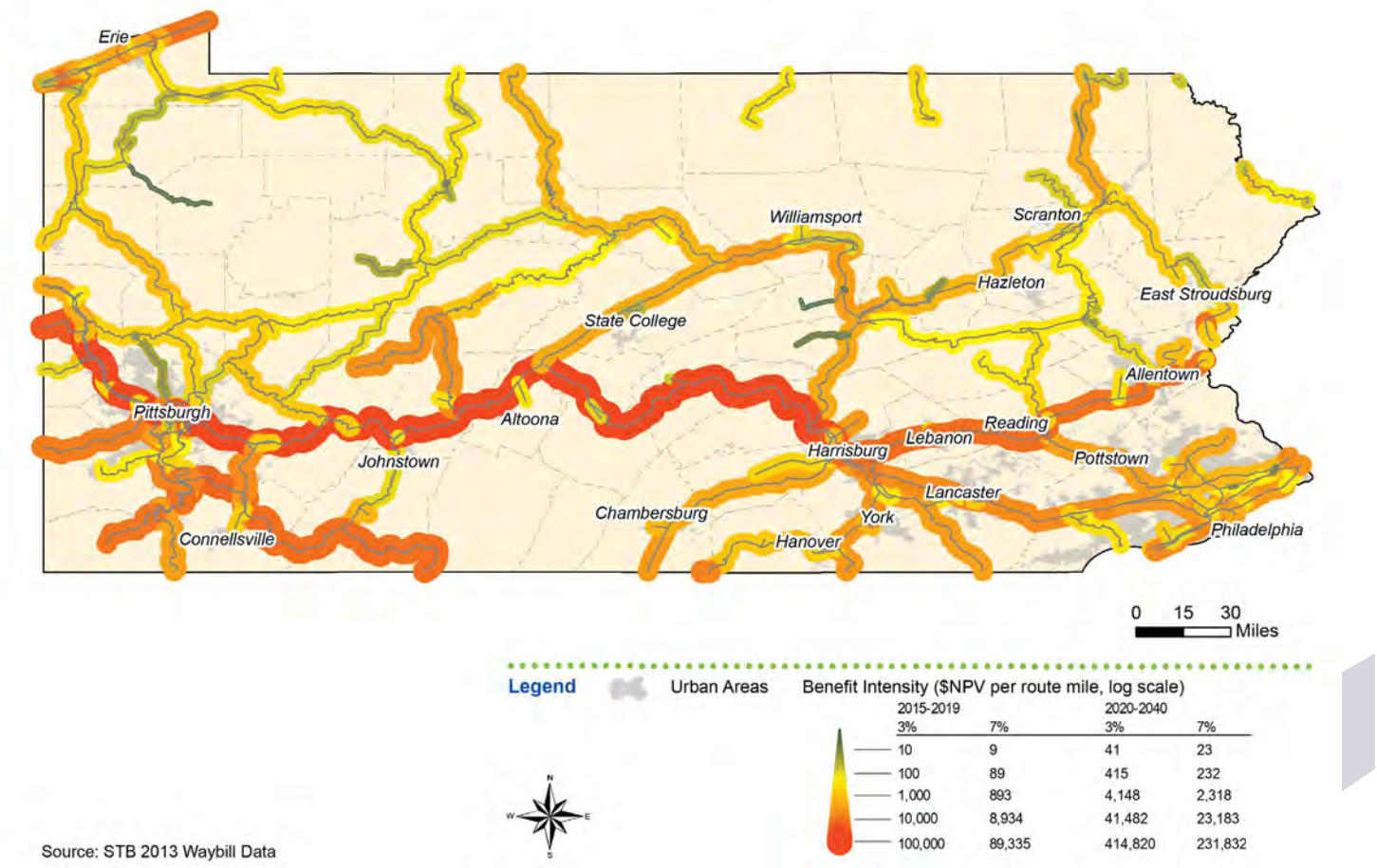
Freight benefits are calculated based on total network ton-miles for all freight flowing in and through Pennsylvania. Calculated at 185 billion ton-miles in 2015, this represents approximately 10 percent of national freight movement. **Table E-15** summarizes freight rail benefits through 2040. **Figure E-3** maps freight network benefits per route segment route mile.

Freight network benefits are strongest along the NS Main Line between Pittsburgh and Harrisburg, followed by the Erie corridor and the CSX Southwest corridor south of Pittsburgh.

Table E-15: Summary of Freight Rail Benefits through 2040 (in millions of 2015 dollars)

	NPV 3%		NPV 7%	
	2015-2019	2020-2040	2015-2019	2020-2040
Operating cost savings	$58,899	$241,659	$52,621	$135,219
Pavement maintenance cost savings	$8,030	$32,948	$7,174	$18,436
Collision reduction	$6,546	$26,856	$5,848	$15,027
Emissions reduction	$5,576	$26,454	$4,977	$14,583
Total	**$79,051**	**$327,917**	**$70,620**	**$183,265**

Figure E-3: Freight Network Benefits per Segment Route Mile



Source: STB 2013 Waybill Data

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