Vehicle Technology Analysis for SEPTA Routes 29 and 79

JULY 2015

DELAWARE VALLEY REGIONAL PLANNING COMMISSION

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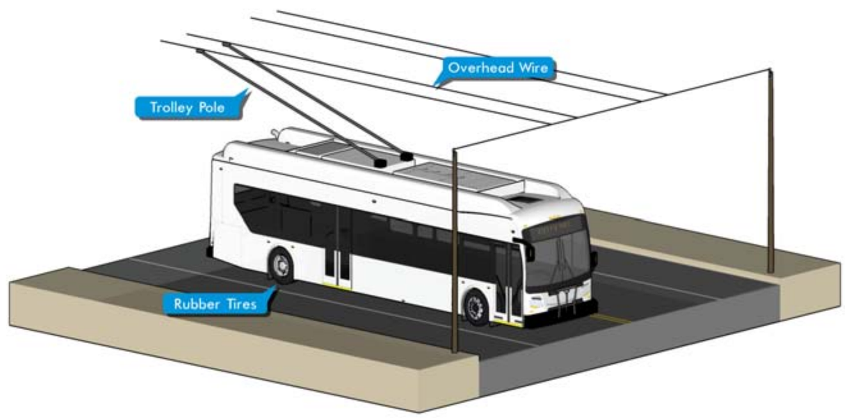


Source: DVRPC 2014

Trackless trolleys, also known as trolley buses, are a transportation mode incorporating elements of streetcars and buses. Like a streetcar, a trackless trolley vehicle is propelled by electric power received from an overhead wire, but—unlike a streetcar— it travels on rubber tires. Historically, the Southeastern Pennsylvania Transportation Authority (SEPTA) operated trackless trolleys on five routes, including routes 29 and 79 in South Philadelphia, the focus of this report. For a number of reasons, SEPTA discontinued trackless trolley service on routes 29 and 79 in 2002 and 2003, respectively, replacing trackless trolley vehicles on those routes with hybrid-electric buses.

In 2010, SEPTA completed an internal analysis of the costs and benefits of restoring trackless trolley service to routes 29 and 79. That analysis concluded that, despite some benefits, trackless trolley restoration for routes 29 and 79 was fiscally infeasible.

In response to community interest in restored trackless trolley service, SEPTA and the City of Philadelphia tasked the Delaware Valley Regional Planning Commission (DVRPC) with providing an updated review of SEPTA's 2010 analysis. In addition to comprehensively reviewing the 2010 SEPTA report's conclusions, DVRPC has also updated several factors that have changed in the years since 2010.

One notable change is the inclusion of battery-electric buses in DVRPC's analysis. Electric bus service has the potential to address many of the community concerns raised in response to the discontinuation of trackless trolley service, namely about noise and pollution. Today, battery-electric bus technology has progressed sufficiently that DVRPC is able to make reliable assumptions about their capabilities and costs. During the course of this report's preparation, SEPTA and the City of Philadelphia each expressed an interest in including battery-electric buses in DVRPC's analysis. Consequently, this report compares the costs and benefits of:

- *trackless trolley* service restoration;
- continued *diesel-electric hybrid bus* service and removal of trackless trolley infrastructure; and
- a *battery-electric bus* pilot program.

This report begins with a description of routes 29 and 79, as well as the history of trackless trolley service in SEPTA's system. The report then evaluates the experiences of peer transit agencies that have recently made capital planning decisions with regard to trackless trolley service. These sections are followed by a description of SEPTA's long-term goals regarding bus and trackless trolley services.

Next, the report contains a lifecycle analysis of each scenario under consideration. Each scenario's section begins with definitions of its respective technology and infrastructure requirements. Those definitions are followed by an evaluation of the scenario's capital, operating, and maintenance costs. These sections also evaluate factors for each scenario that cannot be readily monetized, along with an overall assessment of each scenario's feasibility.

Route Description

Route 29

Route 29 is a crosstown route in South Philadelphia running between the Grays Ferry neighborhood (in the west) and the Pier 70 shopping center (in the east). Vehicles on the route run mostly on Tasker Street (westbound) and Morris Street (eastbound).

The majority of the route runs through dense rowhouse neighborhoods, with important exceptions including Pier 70 (featuring a supermarket and "big box" retail) and Grays Ferry Estates (a housing development of low-rise twins and townhomes that replaced the Tasker Homes housing project).

Until 1947, Route 29 operated as a conventional trolley (or streetcar) route, when the route's former operator, the Philadelphia Transportation Company (PTC), converted it to a trackless trolley route. SEPTA operated trackless trolley service on Route 29 between 1968, when it inherited PTC's routes, and summer 2002, when it replaced trackless trolley service with bus service. The change in vehicles was necessitated by the long-term construction project in which the Tasker Homes were demolished and replaced with the Grays Ferry Estates development. That project forced Route 29 vehicles to detour away from the overhead power source necessary to operate trackless trolleys.

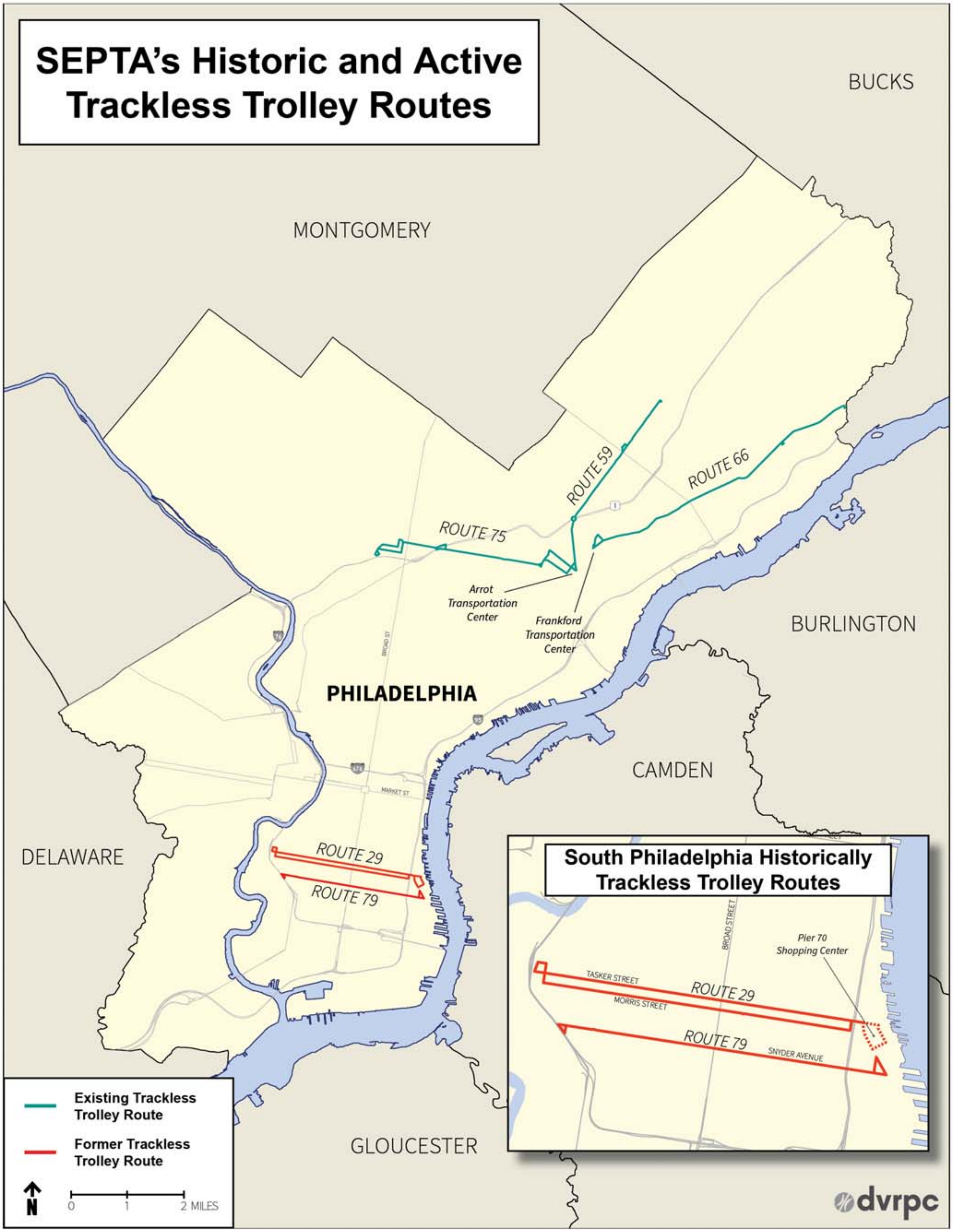
Concurrently, SEPTA extended Route 29 service to Pier 70—to which the route had not previously run. SEPTA reported a spike in ridership as a result of this extension. Critical to this report's analysis, the portion of Route 29 that extends to Pier 70 does not presently include the infrastructure necessary to operate trackless trolley service.

Route 79

Route 79 is a crosstown route in South Philadelphia running between the Point Breeze and Grays Ferry neighborhoods (in the west) and the Columbus Commons shopping center (in the east). Except for turnaround locations at each end of the route, vehicles on Route 79 operate on Snyder Avenue.

Route 79 operated as a conventional trolley route until 1956, when PTC converted it to a bus route. In 1961, PTC converted Route 79 from bus service to trackless trolley service and operated the route in this way through 1968, when it was acquired by SEPTA. SEPTA operated trackless trolleys on Route 79 between 1968 and June 2003, when SEPTA temporarily suspended trackless trolley service citywide as a result of the trackless trolley fleet's age (22–24 years old in 2003) and associated maintenance concerns. Bus service was provided, deploying new diesel-electric hybrid vehicles, which, at the time, represented state-of-the-art propulsion technology for fleet vehicles.

Figure 2: Map of routes that operated or operate trackless trolleys



Source: DVRPC 2014; SEPTA 2014

History and Context

The trackless trolley mode of public transportation has been in use for nearly 100 years. While they remain common in Europe and Asia, only four U.S. cities besides Philadelphia still maintain this mode. The two largest fleets are in San Francisco and Seattle, which benefit from the trackless trolley's efficiency on steep hills as well as nearby sources of clean hydroelectric power (Boston and Dayton are the other two cities).

SEPTA inherited five trackless trolley routes serving north, northeast, and south Philadelphia from the Philadelphia Transportation Company in 1968:

Based at Frankford Garage (North):

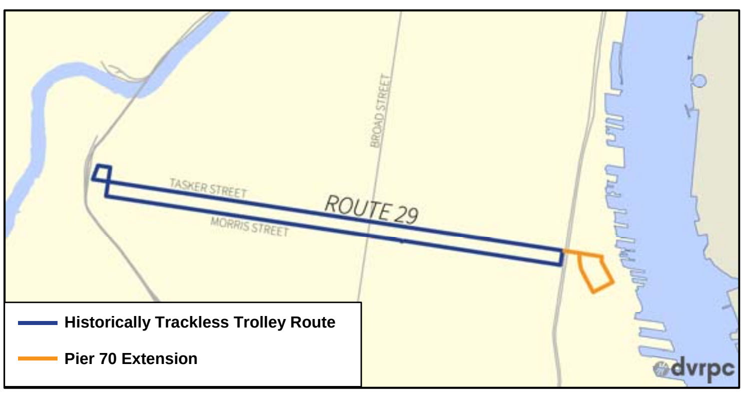
- **Route 59**: Bells Corner to Arrott Transportation Center
- **Route 66**: Morrell Park to Frankford Transportation Center
- **Route 75**: Nicetown to Arrott Transportation Center

Based at Southern Garage:

- **Route 29**: South Philadelphia Crosstown, via Tasker and Morris streets
- **Route 79**: South Philadelphia Crosstown, via Snyder Avenue

By 1981, SEPTA's entire 1940s- and 1950s-era trackless trolley fleet had been replaced with American Motorcoach General (AMG) trackless trolleys. The AMG fleet was beset with reliability issues, which, along with declining ridership, led to service cuts and mothballing of a good portion of the fleet. By 2002, only 66 of the 110 trackless trolleys were still in use for regular service.

Figure 3: Route 29 extension to Pier 70



Source: DVRPC 2014; SEPTA 2014

From 2003–2008, with major construction projects in both northeast and south Philadelphia, SEPTA suspended trackless trolley service entirely and replaced those routes with buses. During this period of suspension, several factors had to be weighed before resuming trackless trolley service. By the mid-2000s, the AMG fleet had exceeded its lifespan and therefore a resumption of service would have required new vehicles. In addition, the overhead wires and substations powering them were in need of modernization, and Route 29 had been extended to the east to service the new Pier 70 Shopping Center. Resuming trackless trolley service on Route 29 would therefore require 0.78 miles of overhead wire installation—some over private property (see Figure 3).

In 2002 SEPTA began acquisition of diesel-electric hybrid buses, and the entire hybrid fleet was assigned to Southern Garage, from which routes 29 and 79 operated. In 2004 SEPTA began restoring trackless trolley service on routes 59, 66, and 75. This restoration was made possible because of FTA grant funding associated with renovations to Frankford Transportation Center. SEPTA purchased 38 new trackless trolleys from New Flyer in 2006, and by 2008 the vehicles had entered service on routes 59, 66, and 75.

The 2006 contract with New Flyer included an option for an additional 23 vehicles, which would have allowed for resumption of trackless trolley service on routes 29 and 79 out of the Southern Garage. SEPTA chose not to exercise the option, considering the capital costs of vehicle acquisition and infrastructure upgrades (e.g., extending overhead wires on Route 29). Nevertheless, environmental groups and community advocates have expressed continued interest in trackless trolley restoration.

Peer Agency Research

Today, only five United States transit agencies operate trackless trolleys in revenue service (by order of fleet size):

- San Francisco Municipal Transportation Agency (SFMTA) – 301 vehicles
- King County Metro (Seattle) – 158 vehicles
- Massachusetts Bay Transportation Authority (MBTA) (Boston) – 60 vehicles
- Greater Dayton Regional Transit Authority (RTA) (Dayton, Ohio) – 54 vehicles
- SEPTA – 38 vehicles

In the last 40 years, no transit agency has implemented a new trackless trolley system, and several agencies have discontinued trackless trolley service. In the last four years, SFMTA, King County Metro, and RTA each undertook studies on whether to continue their trackless trolley system. Each study recommended continuing with the system:

- King County Metro, May 2011. The recommendation was to continue the “trolley bus” system based on the annualized life-cycle cost (considering availability of Federal Transit Administration [FTA] fixed guideway funds), environmental benefits of electric over diesel-electric hybrid vehicles, and that the trackless trolleys operate efficiently on routes with steep grades.

- SFMTA, July 2011. The recommendation was to continue the “trolley coach” system based on the availability of FTA capital fixed guideway funds, zero street-level emissions, superior ability to climb hills, and greater public support.

- RTA, November 2010. The recommendation was to continue the “electric trolleybus” system based on the availability of FTA capital fixed guideway funds, zero street-level emissions, and reliability of the electric fleet over the diesel fleet.

In each peer agency’s review, the level of federal subsidy was a key advantage for trackless trolley service when compared to bus service. FTA categorizes trackless trolleys as a “fixed guideway” mode, the same classification as light rail or heavy rail. The current federal transportation authorizing legislation, the Moving Ahead for Progress in the 21st Century Act (MAP-21), disburses greater formula-based funding for trackless trolley routes than for the same routes when operated as conventional bus routes.[1] In the case of the Seattle

[1] Under the previous federal transportation bill, Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU), trackless trolley service also received greater federal subsidies (compared to bus service), but under a different series of programs.

report, the difference in federal subsidies was a major factor: “the level of fixed guideway funding would have to drop to 31 percent of current funding levels before the [diesel-electric hybrid] bus technology would have a cost advantage.”

However, it is important to note that the Buy America provisions of FTA funding make only one transit vehicle manufacturer eligible for trackless trolley equipment procurement. In addition, the Dayton study noted that electricity generation by coal for the trolleybus may produce more particulate matter and greenhouse gases than would be produced by diesel or diesel-electric hybrid buses. Unlike Dayton, both Seattle and San Francisco benefit from nearby sources of clean hydroelectric power, which along with their hilly terrain, make trackless trolley particularly suited for these cities.

Finally, each of these peer analyses were performed during the previous federal transportation funding and authorization bill, Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). With the passage of a new bill in 2012, MAP-21, the Fixed Guideway Modernization Program was combined with several other programs to form the formula-based State of Good Repair Program. Therefore, any trackless trolley infrastructure project now must compete with other SEPTA rail projects that would be eligible under this program. As SEPTA has a large backlog of state of good repair projects, funding a trackless trolley upgrade project remains challenging.

SEPTA's Goals and Future Directions

While there may be some desire to restore trackless trolley service to routes 29 and 79, industry trends oblige SEPTA and other agencies to consider adopting different or emerging technologies. The 2010 SEPTA trackless trolley report is one example of SEPTA analyzing various possible fleet technologies. Completed in September of 2012, *SEPTA's Bus Fleet Operations: Evaluation of Fueling Options* is another example. This internal report, prepared by SEPTA's Strategic Planning and Analysis staff, explored whether adoption of compressed natural gas (CNG)-powered vehicles would provide superior economic and environmental performance, compared with the existing fleet of clean diesel and diesel-electric hybrid buses. These performance measures have been defined as important to SEPTA in its 2011 sustainability plan, *SEP-TAINABLE: The Route to Regional Sustainability*. Current and future acquisitions are measured and executed in part depending on how they affect the goals laid out in the sustainability plan. For the CNG analysis, it was found that CNG vehicles were generally more expensive to purchase, operate, and maintain than existing vehicle technologies. Furthermore, the CNG vehicles would not offer superior environmental performance, except on the amount of nitrogen oxides emitted. Therefore, this technology would not offer SEPTA significant advantages over current vehicles.

Transit vehicle technology has continued to advance since 2010, when SEPTA last evaluated vehicle selection on routes 29 and 79. In particular, battery-electric buses—which use propulsion technology powered by electrically charged, on-board batteries—are under consideration by several of SEPTA's peer transit agencies. The Société de Transport de Montreal, for example, recently completed a six-month test of battery-electric vehicles from one manufacturer and will begin a three-year test soon of battery-electric vehicle technology from a different firm. Meanwhile, California's Long Beach Transit recently purchased 10 battery-electric buses along with charging equipment. Furthermore, Foothill Transit of the San Gabriel and Pomona Valleys in Los Angeles County put North America's first heavy-duty, battery-electric bus into revenue service in 2014 in its pursuit of operating zero-emission transit.

This flurry of activity has been made possible by rapid advances in electric vehicle technology. Electric bus manufacturers are now offering vehicles that boast a range of up to 155 miles on a single battery charge. Simultaneously, the price of these vehicles has been dropping as more manufacturers enter the market. As with CNG vehicles, SEPTA is interested in exploring whether battery-electric buses can offer capital, operational, and environmental performance that surpasses the existing vehicle fleet.

Because Route 29 and Route 79 have some salvageable infrastructure associated with historic trackless trolley operation, SEPTA has elected to explore the feasibility and cost of restoring trackless trolley service on these routes. With the emergence of battery-powered electric bus technology, SEPTA has also elected to explore this opportunity in the context of an alternative that offers very similar benefits to trackless trolleys, including no point-source emissions and lower operating noise. Battery-powered electric buses have the additional benefits of flexibility to detour off route for extended periods of time when conditions detrimental to service arise.

Scenario Feasibility Comparisons

Three scenarios were analyzed to determine the costs and benefits of each, to determine how they compare to one another and how they meet SEPTA's other goals. To properly compare the three scenarios, each of which involves different vehicles and infrastructure, lifecycle costs were estimated for each. A summary of the cost analysis is listed in the table below and will be discussed in greater detail in an explanation of each scenario.

Table 1: Summary of scenario costs

	Trackless Trolley Restoration	Diesel-Electric Hybrid Bus	Battery-Electric Bus
Capital (per mile)			
Infrastructure Costs	$ 2.40	$ 0.02	$ 0.61
Vehicle Acquisition Costs	$ 3.82	$ 2.21	$ 2.76
Federal Apportionments[2]	($ 2.49)	($ 0.50)	($ 0.50)
Subtotal (Capital)	*$ 3.73*	*$ 1.73*	*$ 2.87*
Operations & Maintenance (per mile)			
Infrastructure Maintenance Costs	$ 0.85	Not applicable	Unknown[3]
Fuel/Power Costs	$ 0.63	$ 0.74	$ 0.27
Vehicle Maintenance Costs	$ 1.54	$ 2.20	$ 1.54
Subtotal (Operations & Maintenance)	*$ 3.02*	*$ 2.94*	*$ 1.81*
Total Lifecycle Costs (per mile)	***$ 6.75***	***$ 4.67***	***$ 4.68***

Source: SEPTA, 2014; Energy Information Administration (EIA), 2014; American Public Transportation Association (APTA), 2013; Proterra, 2014

Each of the three modes under consideration receives a federal apportionment from the Federal Transit Administration (FTA). This subsidy is determined according to a formula, which takes into account each

[2]Current FTA formula funding for trackless trolley service would come from Section 5307 Urbanized Area Formula and 5337 High Intensity Fixed Guideway State of Good Repair programs. Section 5337 High Intensity Fixed Guideway State of Good Repair funds would not become available for the trackless trolley scenario until trackless trolleys had been in operation for seven years. This seven-year lag has been factored into the trackless trolley scenario's federal apportionments calculation.

Current FTA formula funding for hybrid-electric buses and battery-electric buses do or would come from the Section 5307 Urbanized Area Formula and 5339 Bus and Bus Facilities programs.

[3]Depending on the selected electric vehicle technology and manufacturer, some amount of maintenance of charging infrastructure may be necessary. However, as electric vehicle technology is emergent and evolving, these costs are unknown at this time.

route’s vehicle revenue mileage, passenger mileage, and directional mileage on an annual basis. Formula-based apportionments are *not* awarded on a competitive basis.

Presently, FTA does not distinguish between diesel-electric hybrid and battery-electric buses for the purpose of formula funding. Consequently, these two modes would receive identical federal formula subsidies. Trackless trolley routes, on the other hand, receive a more substantial amount of federal formula funding—primarily because trackless trolley routes are considered “fixed guideway” routes by FTA. Fixed guideway modes are calculated according to a different formula, resulting in $2.07 more per mile in federal subsidies for the trackless trolley scenario than for the other two scenarios.

However, battery-electric bus routes and diesel-electric hybrid bus routes are eligible to compete for FTA grant funding under the Low or No Emission Vehicle Deployment Program (LoNo Program), a discretionary funding program that provides capital funding for acquiring low- or zero-emission buses. Because this funding is nationally competitive and not guaranteed, it was excluded from this analysis. The LoNo Program should, however, be a consideration for policymakers considering battery-electric bus or diesel-electric hybrid bus technology.

The federal apportionments presented in this analysis represent the most accurate cost estimates available under MAP-21, the current federal transportation bill. These apportionment estimates, however, are subject to federal reauthorization and could change dramatically over the course of a 15- or 18-year vehicle lifecycle.

SCENARIO 1: Trackless Trolley Restoration

Despite SEPTA's 2008 decision not to restore trackless trolley service to routes 29 and 79, South Philadelphia community groups and environmental and transit advocates have encouraged SEPTA to reexamine its decision. Restoring trackless trolley service would require both capital improvements to bring the existing trackless trolley infrastructure to a state of good repair as well as operating costs that differ from those of the routes' existing bus service. In addition to capital and operating costs, trackless trolley service would also deliver unique environmental and community benefits.

Lifecycle Costs

Because they do not use combustion engines, trackless trolleys benefit from a longer lifecycle than diesel and diesel-electric hybrid buses. For this analysis, trackless trolleys were assumed to have **a useful life of 18 years** (compared to 15 years for diesel-electric hybrid buses and 18 years for battery-electric buses).[4] In order to compare lifecycle costs across vehicles with differing useful lives, lifecycle costs have been standardized and calculated on a per-mile basis.

Capital Costs

Trackless trolleys require comparatively high initial capital costs, mostly attributable to the physical infrastructure required to support their operation. This infrastructure includes elements of on-route infrastructure, depot infrastructure, and substation infrastructure. (See Table 2 for a detailed itemization of trackless trolley infrastructure costs for routes 29 and 79.)

Infrastructure capital costs are particularly high for Route 29 because of the route's extension to Pier 70, which would require 0.78 miles of new on-route infrastructure (see Figure 3). In addition, because Pier 70 is private property, this extension would require some amount of real estate acquisition and/or easement costs associated with placing trolley poles and wires. These real estate costs are unknown at this time and are excluded from this analysis.

Including the on-route infrastructure costs of a Pier 70 extension, **infrastructure for a trackless trolley restoration scenario is estimated to cost $19,534,887**[5] (see Table 2). Crucially, these infrastructure capital costs would need to be paid for in advance of restoring trackless trolley service, as they are necessary to bring the trackless trolley infrastructure to a state of good repair and to provide service to Pier 70.

In order to compare varying forms of infrastructure with varying useful lives, infrastructure costs are presented on a cost-per-mile basis. This per-mile cost was determined by multiplying the annual mileage of all vehicles on routes 29 and 79 (452,871 miles in 2013) by the number of years that trackless trolley vehicles are expected to last (18 years).[6]

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[4]A 15-year useful life for hybrid-electric buses and 18-year useful life for trackless trolleys is based on SEPTA's operational experience. FTA's useful life requirement is only 12 and 15 years, respectively (source: FTA Circular 5010.1D).

[5]These cost estimates do not include potential real estate acquisition or easement costs associated with extending trackless trolley infrastructure to Pier 70.

[6]While the on-route infrastructure for the trackless trolley restoration scenario has an expected useful life of 30 years, costs are calculated over the 18-year fleet vehicle life, in order to enable a comparison between a single vehicle procurement round.

$$\frac{Infrastructure\ Costs}{Annual\ Vehicle\ Mileage \times Total\ Vehicles \times Vehicle\ Lifecycle} = Cost\ Per\ Mile$$

In addition to infrastructure, trackless trolley restoration would require higher capital expenditures for vehicle acquisition. The price for vehicle acquisition used in this analysis, **$1,244,945 per vehicle**, is based on the cost of a trackless trolley vehicle estimated in SEPTA's 2010 report (inflated to 2014 dollars using the U.S. Bureau of Labor Statistics' Consumer Price Index Inflation Calculator), which was estimated based on peer transit agencies' purchases at that time. There is some degree of uncertainty in calculating the price of trackless trolley vehicles. Currently, only one trackless trolley manufacturer meets federal Buy America provisions: New Flyer of America, Inc. This lack of competition may drive up the price of trackless trolley vehicles.

Table 2: Trackless trolley infrastructure costs

Infrastructure Element	Cost
On-route Infrastructure	
Excavate & Install Duct Bank	$ 2,251,491
Replace Trolley Poles (@ 25%)	$ 695,055
Renew Overhead Wire	$ 2,700,331
Install Overhead Feeder Cable	$ 383,786
Install Overhead Feeder Cable Crossarms	$ 43,010
Install Underground Feeder Cable	$ 1,979,050
Install Disconnect Switch (2000 AMP)	$ 16,148
Install Disconnect Switch (600 AMP)	$ 50,734
Install New Trackless Crossings	$ 164,442
Install New Trackless Switches	$ 322,046
Pier 70 Extension: Proportionate Linear Per-mile Costs	$ 813,634
Pier 70 Extension: New Trolley Poles	$ 369,162
Subtotal (On-route Infrastructure Only):	*$ 9,788,889*
Component Retrofit of Mifflin Substation	
Load Analysis	$ 164,367
Demolition of Existing Switchgear	$ 164,367
Building Repairs	$ 328,735
Install Insulated Floor	$ 76,236
AC Breakers and Switchgear	$ 380,785
Rectifier Transformers (1667 kVA)	$ 405,440
Rectifiers (1500 kW)	$ 416,398
DC Cathode Breakers (8000 AMP)	$ 192,858
DC Feeder Breakers (2000 AMP)	$ 854,711
Auxiliary Transformers (300 kVA)	$ 111,770
RTU	$ 53,419
Battery, Battery Charger, Inverter	$ 32,326
Lighting, Ventilation, Wiring, etc.	$ 383,524
Installation Labor	$ 1,190,199
Field Testing & Commissioning	$ 95,103
Subtotal (Component Retrofit of Mifflin Substation Only):	*$ 4,850,238*
Depot Infrastructure	
Install New Trackless Crossings (In Depot)	$ 42,319
Renew Overhead Wire (In Depot)	$ 184,988
Install New Trackless Switches (In Depot)	$ 375,965
Install New Trackless Crossings (At Pull In/Pull Out)	$ 63,479
Renew Overhead Wire (At Pull In/Pull Out)	$ 146,560
Install New Trackless Switches (At Pull In/Pull Out)	$ 187,982
Subtotal (Depot Infrastructure Only):	*$ 1,001,293*
Subtotal:	***$ 15,640,420***
Design and Construction	
Design (@ 8.0%)	$ 1,251,234
Support (@ 6.9%)	$ 1,079,189
Contingency (@ 10.0%)	$ 1,564,042
Subtotal (Soft Costs Only):	$ 3,894,465
Total:	**$ 19,534,885**

Source: SEPTA 2014

Operating and Maintenance Costs

For purposes of this modal comparison, operating costs for trackless trolleys consist primarily of electricity to power trackless trolley vehicles. These costs factor in the price of electricity ($0.0735 per kilowatt hour [kWh]) and the power efficiency of trackless trolleys (8.5267 kWh per mile[7]) to arrive at a per-mile cost.

$$Electric\ Power\ Cost \times Efficiency\ of\ Vehicle = Cost\ Per\ Mile$$

Like any transit vehicle, trackless trolleys require regular maintenance to ensure their operability, including part replacement and associated labor. Vehicle maintenance costs for these two routes were estimated by dividing the total maintenance costs of trackless trolleys on the three Northeast Philadelphia routes (routes 59, 66, and 79) by total vehicle mileage for all vehicles on the same three routes.

$$Total\ Vehicle\ Maintenance\ Costs \div Total\ Vehicle\ Mileage = Cost\ Per\ Mile$$

Trackless trolley service also requires maintenance of its on-route infrastructure, including overhead wire, switches, and other electrical equipment. In 2014, SEPTA's Operating Unit Cost analysis showed that **infrastructure maintenance** costs for the three operational trackless trolley routes in Northeast Philadelphia were **$0.85 per mile**.

Table 3: Cost summary for trackless trolley restoration scenario

Item	Cost per Mile
Capital Costs: Infrastructure Costs	$ 2.40
Capital Costs: Vehicle Acquisition	$ 3.82
Federal Apportionments	($ 2.49)
Maintenance Costs: Infrastructure	$ 0.85
Operating Costs: Electric Power	$ 0.63
Maintenance Costs: Vehicle	$ 1.54
Total:	**$ 6.75**

Source: SEPTA, 2014; EIA, 2014; APTA, 2013

Nonmonetary and Feasibility Factors

In choosing one vehicle type over another, there are many other factors to be considered that are difficult to monetize or that fundamentally affect feasibility. The trackless trolley restoration scenario offers several benefits, particularly when compared to continued diesel-electric hybrid bus service. Many proponents of trackless trolleys focus on the mode's environmental advantages—both in terms of on-route air and noise pollution and in terms of system-wide energy consumption.

Because they do not use combustion engines, trackless trolley vehicles are significantly quieter than diesel or diesel-electric hybrid vehicles. Likewise, a trackless trolley's use of electric propulsion means it produces no

[7] The power efficiency of SEPTA's trackless trolley fleet was derived from FTA's National Transit Database (NTD). In order to identify an early-lifecycle power efficiency rate, the project team selected NTD figures for FY 2009—the first full year of restored trackless trolley operations on routes 59, 66, and 75. The power efficiency rate of 8.5267 kWh per mile was calculated by dividing the 2009 total energy consumption by trackless trolley vehicles (8,131,264 kWh) by the 2009 total mileage by trackless trolley vehicles (953,614 miles). NTD data is available from www.ntdprogram.gov/ntdprogram/data.htm.

point-source emissions. This helps mitigate on-route exposure to emissions, including particulate matter (PM_{10}) and volatile organic compounds (VOCs).[8] Routes 29 and 79 travel through residential rowhouse neighborhoods; the land use and minimal building setbacks of the areas adjacent to these routes make these environmental advantages particularly important. Nevertheless, the energy used to power trackless trolleys is not emission-free. Coal and natural gas are the largest sources of electricity in the Philadelphia region,[9] each of which has negative regional air quality effects and negative climate change impacts.

The trackless trolley restoration scenario suffers from some critical feasibility drawbacks, though. Since being replaced with bus service, Route 29 has served the Pier 70 shopping center, which has since become a major ridership generator for the route. On weekdays and Saturdays, daily ridership at Pier 70 is 600 riders. On Sundays, Pier 70 has 400 daily riders. An extension to Pier 70 would not only require the capital costs associated with new route infrastructure but would also necessitate a legal agreement between SEPTA and the owner of the Pier 70 shopping center to build and maintain that route infrastructure.

Finally, because it is a rarely used mode in North American transit systems, fewer and fewer manufacturers offer trackless trolleys for purchase. If trackless trolley service were restored on routes 29 and 79, SEPTA could not be assured that new trackless trolley vehicles would be available at a reasonable unit price when the next round of procurements are being considered.

[8]King County Metro, *King County Trolley Bus Evaluation*, by Parametrix and LTK Engineering Services, May 2011, p. 5-5.

[9]"Pennsylvania State Profile and Energy Estimates," U.S. Energy Information Administration, accessed December 18, 2013. www.eia.gov/state/analysis.cfm?sid=PA.

SCENARIO 2: Battery-Electric Bus Pilot Program

During 2014, SEPTA considered the feasibility of introducing battery-electric buses into SEPTA's vehicle fleet. This included vehicle demonstrations by three manufacturers. Though technology varies by manufacturer, battery-electric buses use an electric motor powered by a battery that must be periodically charged.

Because this technology is still rapidly developing, costs for this option are considered approximate. Exact costs would not be known without further pursuing this option. Introduction of electric buses would likely be done on a pilot basis to determine how these vehicles performed in typical operating conditions and to determine the real costs and benefits of these vehicles for SEPTA. Therefore, the costs below are for a pilot project for routes 29 and 79.

Lifecycle Costs

As stated above, a lifecycle cost analysis is necessary to properly compare each option. Lifecycle costs include the capital, operating, and maintenance costs for a battery-electric bus pilot project. Like trackless trolleys, battery-electric buses use an electric propulsion system that does not suffer from the deterioration effects inherent in internal combustion engines. Based on this assumed mechanical similarity to trackless trolley vehicles, **the costs provided for the battery-electric bus scenario are based on an 18-year useful life** (the same life span as trackless trolley vehicles). Costs are provided on a per-mile basis.

Capital Costs

The greatest capital cost for a battery-electric bus pilot would be vehicle acquisition. Based on SEPTA's discussions with various manufacturers, it is estimated that the cost per vehicle would be $825,000. It is also assumed that the battery will need to be replaced once within the life of each vehicle. The cost of battery replacement is estimated to be $75,000. **The total vehicle cost would be $900,000 or $2.76 per mile** assuming an 18-year useful life and total mileage of 326,070 over the course of one lifecycle. Total lifecycle mileage was calculated by multiplying the average annual mileage for vehicles on routes 29 and 79 by the number of years in a battery-electric bus's expected useful life—18.

The next category of capital costs are those related to battery charging infrastructure. Because battery charging technologies differ by vehicle, the charging infrastructure costs vary by the manufacturer. One set of vehicles would charge along the route as well as at Southern Depot. Five charging units would be necessary to keep these vehicles operational. This includes fast-charging units along each route as well as one unit at Southern Depot. Each charging unit costs roughly $1,000,000, for a total of $5,000,000 for these two routes. Other vehicles would charge only at Southern Depot and no charging stations would be necessary, though the depot would likely need to be retrofitted to process increased amounts of electricity.

An **infrastructure capital cost of $5,000,000** was selected, regardless of manufacturer, in an attempt to capture the unknown costs associated with a Southern Depot retrofit, should SEPTA purchase vehicles with that charging technology. As with capital costs for trackless trolley infrastructure, these costs are presented on a per-mile basis, reflecting the mileage for all vehicles on routes 29 and 79 over an 18-year useful lifespan. Using this methodology, this analysis estimates **battery-electric bus infrastructure costs of $0.61 per mile.**

Operating and Maintenance Costs

The two costs necessary for ongoing operations are fuel/power costs and vehicle maintenance costs. SEPTA has received expressions of interest from several battery-electric bus manufacturers, who have provided fuel economy data based on field tests on Philadelphia streets. After reviewing this information, the project team identified a cost of **$0.27 per mile for electric power** needed to operate battery-electric buses.

Since these technologies are relatively untested, maintenance costs for electric vehicles on these routes are speculative. However, since the vehicles are somewhat similar to the trackless trolley vehicles (they do not have combustion engines, and they have similar propulsion mechanisms and components), for this analysis it is assumed that battery-electric buses and trackless trolleys would have the same **maintenance cost per mile of $1.54**. Peer experience validates this assumption; several North American transit agencies have reported electric vehicle maintenance costs that are generally similar to those of trackless trolleys.[10]

Table 4: Cost summary for battery-electric bus pilot program scenario

Item	*Cost per Mile*
Capital Costs: Infrastructure	$ 0.61
Capital Costs: Vehicle Acquisition	$ 2.76
Federal Apportionments	($ 0.50)
Operating Costs: Electric Power	$ 0.27
Maintenance Costs: Vehicle	$ 1.54
Total:	**$ 4.68**

Source: SEPTA 2014; EIA 2014; APTA 2013; Proterra 2014; BYD 2014

Nonmonetary and Feasibility Factors

Battery-electric buses have a number of environmental benefits that are difficult to monetize. First, these vehicles are quieter than diesel-electric hybrid buses because they do not use combustion engines. These vehicles also have benefits for local air quality as there are no emissions along the route. However, this benefit must be balanced with the increase in regional emissions from power generation spurred by greater electricity use, which contributes to climate change. Switching to zero-emission electric vehicles would shift the burden to produce fewer emissions from the transportation sector to the energy production sector of the economy.

Moving forward with battery-electric vehicles would allow SEPTA many of the same operational benefits as with diesel-electric hybrid buses. Extensions of service would be significantly simpler under a battery-electric bus scenario than a trackless trolley scenario. Service to Pier 70, for example, would be able to be maintained without any costly infrastructure extensions. Also, unlike with trackless trolley vehicles, detouring for construction or other closures or delays would be much easier operationally. These abilities have many operational and service benefits for both SEPTA and current riders.

[10] DVRPC broadly examined the maintenance experiences of agencies in Chattanooga, TN, and Missoula, MT, as well as an academic analysis from Florida State University. Maintenance costs for electric transit vehicles varied, but they tended to cost 20–40 percent less to maintain than their diesel-fueled counterparts—similar to the difference in maintenance costs between trackless trolley vehicles and diesel-electric hybrids.

SCENARIO 3: Diesel-Electric Hybrid Buses with Trackless Trolley Infrastructure Removal

The final scenario is the continuation of service on these routes by diesel-electric hybrid buses and the removal of trackless trolley infrastructure. Removing trolley infrastructure would demonstrate that trackless trolley service is not returning to these corridors and would have an aesthetic benefit for the public space along these routes.

Lifecycle Costs

Lifecycle costs for this scenario are based on a 15-year lifecycle for diesel-electric hybrid buses and also include capital, operational, and maintenance costs associated with service by these vehicles. Costs are presented on a per-mile basis so that the three scenarios can be compared.

Capital Costs

Although the vehicles that operate along these routes have been acquired, eventually these vehicles will need to be replaced. Additionally, to compare the scenarios, vehicle acquisition was assumed to be necessary for each scenario. Based on American Public Transportation Association (APTA) database figures, each diesel-electric hybrid bus costs approximately $567,678 in 2014 dollars. Additionally, each bus requires one battery replacement during its lifetime. Battery replacement costs $32,348, which brings the total lifetime cost per vehicle to $600,026. **During a 15-year lifecycle, each vehicle would accumulate approximately 271,725 miles, for a cost of $2.21 per mile.**

Infrastructure capital costs for this scenario come from removing the existing trackless trolley infrastructure. SEPTA would be responsible for removing overhead wires and poles. SEPTA estimates that removing these items would likely take three months and would cost about $100,000. That would include removing the contact wire, cross spans, and aerial feeders. It is likely that some poles would remain and possibly be turned over for ongoing use by other utilities. Consequently, the cost associated with pole removal would depend on the number of poles removed. **The estimated total cost for these two items is $125,000**, with the potential for some amount to be returned to SEPTA because of scrap value.[11]

As with each other scenario, infrastructure costs are presented on a per-mile basis to allow comparison across modes with varying vehicle lifespans. This per-mile cost takes into account the mileage for all vehicles on Routes 29 and 79 over a 15-year useful lifespan. Using this methodology, this analysis finds **infrastructure capital costs for the diesel-electric hybrid bus scenario of $0.02 per mile.**

Operating and Maintenance Costs

The operations and maintenance costs associated with diesel-electric hybrid buses are diesel fuel and vehicle maintenance. The assumed diesel fuel cost per gallon is $2.87. The current fleet of diesel-electric hybrid vehicles averages 3.87 miles per gallon, so **the operation cost per mile is $0.74.**

The other cost related to ongoing operation is **vehicle maintenance**. For SEPTA's diesel-electric hybrid fleet, this cost is **$2.20 per mile**.

[11] Removing the decommissioned Mifflin Substation might also be considered and would likely have some scrap value. However, it is beyond the scope of this analysis to estimate the costs and benefits of this action.

Table 5: Cost summary for continued bus service and trackless trolley infrastructure removal

Item	Cost per Mile
Capital Costs: Infrastructure	$ 0.02
Capital Costs: Vehicle Acquisition	$ 2.21
Federal Apportionments	($ 0.50)
Operating Costs: Diesel Fuel	$ 0.74
Maintenance Costs: Vehicle	$ 2.20
Total:	**$ 4.67**

Source: SEPTA, 2014; EIA, 2014; APTA, 2013

Nonmonetary and Feasibility Factors

The two major negative factors of serving these routes with diesel-electric hybrid buses are noise and local air quality. Unlike the other two scenarios in this analysis, this scenario would involve vehicles with combustion engines, which are noisier than their battery-electric counterparts. Likewise, although the hybrid nature of these buses reduces vehicle emissions, there still are tailpipe emissions when the vehicle's engine is not running on battery power. The ongoing use of fossil-fuel combustion also contributes to global climate change.

However, under this scenario there are a number of benefits for SEPTA and the communities around these routes. The communities would experience aesthetic benefits from the removal of the trackless trolley power infrastructure. From SEPTA's perspective, removing this infrastructure would end the need for ongoing maintenance.

Both riders and SEPTA also benefit from the routing and detouring flexibility of the diesel-electric hybrid buses. Additionally, as Route 29's existing extension to Pier 70 demonstrates, diesel-electric hybrid buses enable routes to be extended to serve new markets much more easily than trackless trolley routes.

Conclusions

Each of the three scenarios presented in this analysis offer a unique set of costs, benefits, risks, and rewards.

Cost Determination

When per-mile lifecycle costs are calculated, clear differences emerge between the three scenarios under consideration. Trackless trolley is the most expensive scenario, at $6.75 per mile. This cost was primarily the result of high capital costs—both for route infrastructure as well as for vehicle acquisition.

The capital expense associated with trackless trolley restoration would expose SEPTA to long-term risk. Capital costs in excess of $19 million are required to bring infrastructure on routes 29 and 79 to a state of good repair—significantly more upfront infrastructure investment than the costs associated with either of the other two scenarios. In addition, that infrastructure's costly maintenance requirements put trackless trolley restoration at a significant disadvantage when compared to the other two scenarios.[12]

More generally, having recently acquired increased state funding under Act 89 of 2013, SEPTA is currently engaged in its Rebuilding for the Future program, designed to address a $5 billion backlog of state of good repair needs. Any infrastructure capital costs for trackless trolley restoration would have to compete for funding with SEPTA's many state of good repair projects.

The trackless trolley scenario's high capital costs are somewhat mitigated by relatively low fuel and maintenance costs as well as, most importantly, greater federal subsidies. The low cost of electric power, and lower maintenance costs associated with battery-electric vehicles, make trackless trolley operations costs less expensive than diesel-electric hybrid operations costs but do not provide a cost advantage over the battery-electric bus scenario.

The main cost advantage to trackless trolley restoration comes as a result of current federal subsidies. Because trackless trolley service qualifies as fixed-guideway service for purposes of federal funding, routes 29 and 79 would receive more than $1 million in additional federal apportionments each year as trackless trolley routes than as diesel-electric hybrid bus routes or battery-electric bus routes, based on current formula allocations. This equates to $2.07 per mile more in subsidies for trackless trolley service. It is important to consider, however, the unpredictability of federal subsidies for trackless trolley service. Recent federal transportation funding statutes have typically been authorized for approximately two to six years before being replaced by successor bills. To put this timeframe in perspective, one federal funding program, the Section 5337 program, would not even become available until trackless trolley vehicles were operational for 7 years. Trackless trolley vehicles have lifecycles of 18 years, and trackless trolley infrastructure is expected to have a useful life of roughly 30 years. As a result, relying on MAP-21, the current federal transportation bill, to account for federal trackless trolley subsidies many years into the future would expose SEPTA to long-term funding uncertainty after the initial capital investment has been made.

On the opposite end of the spectrum, continuing diesel-electric hybrid service requires minimal capital cost. SEPTA's engineering staff estimated that the net cost of removing on-route trackless trolley infrastructure and

[12] While this analysis has shown that trackless trolley service has important drawbacks on routes 29 and 79, specifically, the same conclusions cannot necessarily be drawn about other routes within SEPTA's system. Before reconsidering existing trackless trolley service on routes 59, 66, and 75, or before introducing trackless trolley service to other transit routes, SEPTA should perform a route-specific analysis to determine that particular route's preferred transit mode.

selling the resulting salvageable scrap materials was approximately $125,000—only $0.02 per mile, when calculated over a diesel-electric hybrid bus's 15-year lifecycle.

Though diesel-electric hybrid buses are less expensive to purchase, diesel fuel costs and maintenance costs reduce the mode's competitiveness on a per-mile basis. Additionally, because diesel fuel prices are more volatile than prices for electricity, operating diesel-electric hybrid buses on routes 29 and 79 exposes SEPTA to greater risk of increased fuel prices than operating vehicles with electric motors.

The battery-electric bus scenario offers an opportunity to provide many of the same benefits as trackless trolleys, but with less capital investment. It is important to note, however, that some assumptions about battery-electric bus service are speculative because SEPTA does not have the service record with these vehicles that it does with diesel-electric hybrid buses and trackless trolleys. Therefore, data about these vehicles is mostly provided by the manufacturers. For example, the capital costs for route infrastructure (including either charging stations or garage retrofits) are comparatively low, but not insignificant. SEPTA should stay informed of developments in battery-charging technology that could make battery-electric bus infrastructure more cost-effective and easier to integrate into its existing routes.

Other cost estimations for battery-electric buses also remain somewhat uncertain, but they are assumed to be lower than either trackless trolleys or diesel-electric hybrid buses. Battery-electric buses are more expensive to purchase than diesel-electric hybrid buses, but less expensive than trackless trolleys. Battery-electric buses are assumed to have the same maintenance cost advantages as trackless trolleys, and their greater fuel efficiency makes them even more competitive on a per-mile basis. There are currently no formula-based federal subsidies available specifically for battery-electric bus operations, leaving them with the same federal funding outlook as diesel-electric hybrid buses. As described above, however, FTA subsidizes vehicle acquisition and other capital costs for low- or zero-emission transit vehicles under its competitive LoNo grant program. On February 5, 2015, FTA announced grants of over $33 million to seven U.S. transit agencies for battery-electric bus deployment—suggesting that discretionary funding could be available to help offset the costs of a battery-electric bus pilot program.[13]

Nonmonetary and Feasibility Determination

Trackless trolley service would, however, offer significant nonmonetary benefits. Trackless trolleys produce no point-source emissions, and they are significantly quieter than diesel-electric hybrid buses—key benefits to residents along routes 29 and 79. Moreover, restoring trackless trolley service is an opportunity for SEPTA to improve greenhouse gas and criteria air pollutant emissions performance, a key goal detailed in its sustainability plan, *SEP-TAINABLE: The Route to Regional Sustainability*.

On the other hand, trackless trolleys are limited in their off-route maneuverability, which would affect high-ridership stops at Pier 70 or would affect either route during detour situations. Trackless trolley vehicles may also become increasingly difficult to acquire in the future, as there is only one vendor currently producing trackless trolley vehicles that meet federal Buy America requirements.

Because it would also use electric propulsion technology, battery-electric bus service would achieve the same environmental benefits as trackless trolley service. A clear advantage for battery-electric bus service, however, is that it would not be limited in its routing and detour abilities.

[13]"Low or No Emission Vehicle Deployment Program Project Selections," last modified February 5, 2015. www.fta.dot.gov/grants/15926_16268.html.

Diesel-electric hybrid buses are more efficient and pollute less than their all-diesel predecessors, but when compared to either trackless trolleys or battery-electric buses, they are still at a clear disadvantage.

The local community and environmental benefits of trackless trolley and battery-electric bus service are clear, and only battery-electric buses can achieve these benefits without limited detour and routing abilities. These conditions make battery-electric buses the most advantageous option. Battery-electric buses, however, are still an emerging technology with consequent financial and functional uncertainties. Before introducing battery-electric buses into revenue service on routes 29 and 79—or on any other SEPTA bus routes—SEPTA should perform an analysis to identify route selection criteria for battery-electric buses. In addition, SEPTA should explore opportunities to test this battery-electric bus technology as part of a pilot program. Piloting this technology for demonstration purposes may have the additional benefit of being eligible for FTA demonstration funds, which could help offset the risk inherent in adopting new vehicle technology.

Appendix A

Appendix A: Bibliography

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Vehicle Technology Analysis for SEPTA Routes 29 and 79

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Abstract:
This report compares the costs and benefits of:

- *trackless trolley* service restoration;
- continued *diesel-electric hybrid bus* service and removal of trackless trolley infrastructure; and
- a *battery-electric bus* pilot program.

This report begins with a description of routes 29 and 79, as well as the history of trackless trolley service in SEPTA's system. The report then evaluates the experiences of peer transit agencies that have recently made capital planning decisions with regard to trackless trolley service. These sections are followed by a description of SEPTA's long-term goals regarding local bus and trackless trolley service. The report continues with a lifecycle cost analysis comparing the three above-mentioned operating scenarios. This analysis informs a feasibility determination based on costs as well as nonmonetary factors.

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