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Economic Benefits of Additional Rail Bridge Capacity: A Case Study on the Benefits of Replacing the Merchants Bridge Main Spans at Saint Louis

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Final Report
November 2015

Sponsored by
Terminal Railroad Association of St. Louis
Midwest Transportation Center
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Office of the Assistant Secretary for
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The Merchants Memorial Mississippi Rail Bridge and MacArthur Bridge over the Mississippi River make up the most heavily used Mississippi River rail crossing in the country. A large contributor to the popularity of the Merchants Bridge is its accessibility to all railroads. However, the bridge is 126 years old and in significant need of repair.

Without improvements, the bridge will close in 2034 and all current traffic will be rerouted to longer routes, resulting in hundreds of extra miles traveled and more time spent. Repairing the bridge will cost approximately $250 million for construction, which includes the additional costs of closing the bridge during the repairs.

However, the project is set to generate billions of dollars in cost savings in the coming decades. At a discount rate of 7%, improving the Merchants Bridge will lead to nearly $4.7 billion in net benefits over the next 20 years and approximately $6.6 billion in the next 30 years.

These benefits will not only be realized by the transportation industry, they will help the entire region. Therefore, reconstructing the Merchants Bridge will generate economic benefits that will protect the most heavily used Mississippi River rail crossing and provide sizeable benefits to the public, at large.

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Final Report
November 2015

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EXECUTIVE SUMMARY

The Merchants Memorial Mississippi Rail Bridge and MacArthur Bridge over the Mississippi River make up the most heavily used Mississippi River rail crossing in the country. A large contributor to the popularity of the Merchants Bridge is its accessibility to all railroads. However, the bridge is 126 years old and in significant need of repair.

Without improvements, the bridge will close in 2034 and all current traffic will be rerouted to longer routes, resulting in hundreds of extra miles traveled and more time spent. Repairing the bridge will cost approximately $250 million for construction, which includes the additional costs of closing the bridge during the repairs.

However, the project is set to generate billions of dollars in cost savings in the coming decades. At a discount rate of 7%, improving the Merchants Bridge will lead to nearly $4.7 billion in net benefits over the next 20 years and approximately $6.6 billion in the next 30 years.

These benefits will not only be realized by the transportation industry, they will help the entire region. Therefore, reconstructing the Merchants Bridge will generate economic benefits that will protect the most heavily used Mississippi River rail crossing and provide sizeable benefits to the public, at large.

INTRODUCTION AND HISTORY

Located in St. Louis, Missouri, the Merchants Bridge joins Missouri and Illinois and has stood as one of the nation's most important Mississippi River rail crossings for 126 years. Combined with the MacArthur Bridge, the Merchants Bridge makes up the most heavily used Mississippi River rail crossing in the country. With a combined average of 72.8 trains per day (TRRA 2015a), this system transports nearly 10 more trains per day on average than the crossing with the second highest traffic count and 30 more trains per day than the bridge with the third highest count.

More importantly, unique to this crossing is that it is open to all railroads. Most high-trafficked Mississippi River rail bridges are privately owned by railroad companies that only allow their own trains to use the tracks. However, the Merchants and MacArthur Bridges are owned by the Terminal Railroad Association (TRRA) and can be used by any railway. In this way, the Merchants-MacArthur Bridge system makes up one of the most important pieces of infrastructure for east-west rail transportation. However, due to age and use, the Merchants Bridge is nearing the end of its useful life. In order to ensure the longevity of this infrastructure, the Merchants Bridge requires replacement.

Built in 1890, the Merchants Bridge suffers from structural deterioration and currently operates at a limited capacity due to weight restrictions. Although the bridge contains two sets of tracks, it essentially functions as a single-track bridge, which causes freight to bottleneck on either side of the Mississippi River as capacity levels are exceeded. Replacing the main spans of the Merchants Bridge would not only lift the weight restrictions, thereby alleviating the current congestion, it could also ameliorate the traffic on other heavily used routes, which would cut costs and generate benefits for the region as a whole.

The Federal Railroad Administration (FRA) predicts that the total tonnage moved by rail will increase 35% from 12.5 billion in 2010 to 16.9 billion in 2050 (FRA 2010). From this figure, the calculated annualized growth rate for rail tonnage is 0.78%. Because the Merchants Bridge is utilized by all railroads and is a vital crossing for east-west freight, this growth projection can be applied to future volumes on the bridge. Therefore, under current conditions, the expected annual freight tonnage crossing the Merchants Bridge is forecasted to increase by 0.78% annually, assuming no further deterioration. However, considering the age and condition of the Merchants Bridge, this assumption is highly conservative.

With an industry average of 3,488 tons per train (AAR 2015), the current freight volume for the Merchants Bridge is calculated to weigh approximately 110,220.8 tons per day, using an average of 32.2 daily train crossings (TRRA 2015a). At a peak single-track volume of 40 trains per day (TRRA 2015b), this figure rises to 139,520.0 tons per day. Where peak volume is an indicator of maximum capacity on the weight-restricted bridge, this figure means that when applying the annual growth rate to current traffic flow, expected volumes on the Merchants Bridge will naturally exceed peak volume capacity for the bridge's current state by 2042.

However, this capacity will never be reached because if the Merchants Bridge is not replaced, it will close in 2034. Thereafter, the freight that is currently transported across the Merchants

Bridge will be redirected to alternative routes. These routes will require longer distances and will take more time to traverse. Without the Merchants-MacArthur Bridge system, the nearest Mississippi River crossing open to all railroads will require an additional 300 miles of travel. This means that if the Merchants-MacArthur Bridge crossing is either congested or out of commission, freight will be diverted an extra 300 miles in order to reach the same destination. The subsequent increase in mileage and travel time can be directly quantified into significantly higher costs.

Another argument for replacing the Merchants Bridge is that while the MacArthur Bridge is in better condition, it is also aging. In several decades, the MacArthur Bridge will also require maintenance or risk closure. Improving the capacity of the Merchants Bridge now will ease the traffic that will be impacted by the closure of the MacArthur Bridge in the future. Without a working Merchants Bridge, closing the MacArthur Bridge will completely cut off both halves of the most heavily-trafficked Mississippi River crossing in the country. Furthermore, by improving the Merchants Bridge, some of the traffic currently crossing the MacArthur Bridge can be alleviated, which in turn will decelerate the deterioration of the MacArthur Bridge and delay the need for future repairs. Avoiding the potential closure of both pieces of infrastructure is imperative to keeping rail transportation operating efficiently in the future as the demand for freight continues to grow.

The cost-benefit analysis for this project is conducted by aggregating all benefits and costs associated with repairing the Merchants Bridge and comparing those to the benefits and costs incurred should the project not proceed and should the bridge close in 2034. By contrasting the two, this analysis depicts the total economic benefit that will be realized by improving the Merchants Bridge.

DEVELOPING A COST-BENEFIT MODEL

The cost-benefit analysis compares the baseline if improvements are not made to the Merchants Bridge to the build alternative if the Merchants Bridge is repaired. Over time horizons of 20 and 30 years, the net present value (NPV) benefits are provided at a 3% and 7% discount rate, as well as in undiscounted values, per the 2014 U.S. Department of Transportation (DOT) Transportation Investment Generating Economic Recovery (TIGER) guidelines (U.S. DOT 2014). Discounting begins with the year 2017 as period zero, the year the first dollars are invested in the project. Because in the absence of bridge replacement the Merchants Bridge is scheduled to shut down in 2034, which falls within the initial 20 year period, there is a drastic increase in NPV between the two time horizons. As such, it is important to look beyond the first 20 years and consider the projected benefits that would be lost throughout the 30 year horizon if the Merchants Bridge is allowed to close. These losses would be experienced not only by the transportation industry, but by the entire region.

Baseline Alternative

The baseline alternative represents conditions if improvements are not made to the Merchants Bridge. Here, the bridge will operate at its current capacity until 2034 when it reaches the end of its useful life. However, as the bridge continues to age, maintenance costs to keep it in operation will also rise annually. Upon its closure in 2034, all traffic that currently uses the bridge will be redirected to alternative routes. This will create longer transport times and more traffic on already congested rail lines. The primary assumption for the baseline alternative is that the current bridge capacity will remain constant until the bridge’s closure in 2034.

Build Alternative

The build alternative represents the total costs and benefits experienced if the project moves forward and the Merchants Bridge is repaired. Construction would begin in 2017 and is expected to conclude in 2020. It is during this period that the build alternative costs would be incurred and bridge outages would be experienced as the main spans are replaced. These outages are expected to account for less than three weeks per year for each year from 2017 to 2020. For a conservative estimate, the model assumes the upper boundary of 21 days of outages per year. However, after completion, the project benefits would immediately be realized. The expected completion date is set for December 2019.

The increased capacity of the improved bridge would not only divert future traffic from otherwise traveling across more distant rail lines, it would also prevent current traffic from rerouting as well. With the higher capacity on the double-track bridge, the predicted change in annual freight tonnage traveling across the Merchants Bridge is expected to increase from the current 40 million gross tons (MGT) to 100 MGT per year (McCarthy and Fields 2015). This equates to an additional 60 MGT each year that would have otherwise cost more time and money to reach each respective destination.

The build alternative not only prevents longer rail routes, it also decreases the amount of freight traffic on highways. Ton for ton, shipping freight by rail is cheaper than by truck. Consequently, if capacity on the Merchants Bridge is expanded, freight that would otherwise be transported by truck will shift to rail as a means of minimizing costs. The degree to which intermodal truck freight will decrease depends on the current percent of intermodal freight currently transported along the Merchants Bridge. Holding this percentage constant as capacity increases, the total influx in intermodal freight can be assumed to come from diversion from truck to rail.

After reconstruction, the Merchants Bridge will also continue to serve as an Amtrak route from St. Louis to Chicago. The route will become more reliable, thereby rendering passenger travel between the cities easier. As such, the project is expected to have a positive benefit for intercity travel. However, this cost-benefit analysis focuses on the benefits of increasing freight transport rather than passenger transport. Therefore, it is important to note that although the benefits of maintaining an Amtrak line along an improved Merchants Bridge are expected to be positive, they are not included in this analysis. Their inclusion would result in even higher total benefits for the build alternative.

QUANTIFYING PROJECT BENEFITS

The project benefits of replacing the Merchants Bridge can be grouped into three categories: transportation cost savings, environmental cost savings, and inventory cost savings. Moreover, the categories can further be divided according to the areas where those savings are generated. Rebuilding the bridge will increase capacity, increase transport speeds, and also decrease the amount of freight that would otherwise travel along highways. When freight is diverted, this not only translates into more miles traveled, but also more time spent. By comparing the baseline alternative to the build alternative, an incremental number of freight ton-miles can be calculated, as well as an incremental number of travel hours. These values represent the decrease in freight ton-miles traveled and the decrease in total hours spent as a result of replacing the bridge. From there, the benefits can be quantified and aggregated.

This section describes how the benefit categories are measured. With the exception of bridge maintenance cost savings, benefits will not be realized until the beginning of 2020, after the completion of the project in December 2019. Appendix A shows the project benefits by category for each year between 2017 and 2046. Appendix B details the logic structure used to compute each benefit category. Inputs used for this cost-benefit analysis are included with their sources in Appendix C of this document. A summary of the cost-benefit analysis findings are presented in the following chapter of this report. All dollar values are given in real 2015 dollars.

Transportation Cost Savings by Not Diverting Freight to Longer Rail Routes

Labor costs make up a sizeable portion of transportation cost savings as a result of not diverting to longer routes. Assuming an average of two rail operators per train, this amounts to approximately $92.32 for each additional hour of travel on the longer route. This figure is derived from the 2014 TIGER guidelines for the hourly cost of transit rail operators and assumes two operators per train. Moreover, the incremental diesel fuel spent by traveling longer distances can also be calculated using the average fuel burned per rail ton-mile. More miles also means higher costs in maintenance, accidents, and congestion, which are quantified using per ton-mile cost estimates.

The opportunity cost of using the railcars and locomotives is also factored into the transportation cost savings category. When the vessels are being used to transport freight along longer rail routes, they are not available for other purposes. Although the freight reaches the same destination, it takes more hours to do so, causing the opportunity cost to increase. In this way, there is a price to using freight cars and locomotives, as measured in the cost per additional hour of travel.

Environmental Cost Savings by Not Diverting Freight to Longer Rail Routes

The majority of environmental cost savings by not diverting freight to longer routes are measured by increased pollution emissions. Nitrogen oxide (NOx), particulate matter (PM), volatile organic compounds (VOC), and carbon dioxide (CO_2) all have a cost per ton as defined by the 2014 TIGER guidelines. When the total freight ton-miles increases by transporting freight along longer routes, this burns more fuel and releases more emissions. These emissions are then quantified and amalgamated into total environmental cost savings. Additionally, the extra mileage also creates more noise. An estimate for the cost of noise pollution per rail ton-mile is also added to environmental cost savings.

Inventory Cost Savings by Not Diverting Freight to Longer Rail Routes

In addition to the opportunity cost of using the railcars and locomotive engines, there is also a cost of delaying the lading of future shipments. For each hour a train is delayed, the loading of new merchandise onto the vessels must be postponed. This translates into foregone revenue because less inventory can be moved. Therefore, reducing travel times by not diverting to longer routes will also produce inventory cost savings as defined by the opportunity cost of delayed lading.

Transportation Cost Savings Due to Run Time Improvements

Currently, the average speed for trains to cross the Merchants Bridge is approximately 6 miles per hour due to single-track limitations. In the case of bridge improvements, this average speed is projected to more than double to 14 miles per hour, thereby halving travel time over the bridge. The incremental hours saved due to run time improvements will save on the personnel costs and the opportunity costs of using the railcars and locomotives. Furthermore, the increased run time improvements will also save fuel as idling time for locomotives decreases. The incremental gallons of fuel are quantified and measured as the cost per gallon of diesel, which is also included in transportation cost savings due to run time improvements.

Environmental Cost Savings Due to Run Time Improvements

The additional diesel fuel spent is used to compute the total increase in emissions of NOx, PM, VOC, and CO_2. Noise pollution is not included in this category because it is measured in cost per ton-mile, and an increase in run time improvements will not change the total ton-miles traveled.

Inventory Cost Savings Due to Run Time Improvements

This category is computed by applying the opportunity cost of delayed lading to the incremental hours saved due to run time improvements.

Transportation Cost Savings from Diverting Freight from Truck to Rail

Transport costs in this category are quantified by comparing the cost of transporting intermodal freight by rail over an improved Merchants Bridge to the cost of transporting freight that same distance by truck, using average transport speeds for both vessels. Fuel, labor, maintenance costs, congestion costs, and accident costs all contribute to this category. Per ton-mile, trucks burn over three times more diesel fuel than trains. As a result, fuel represents one of the largest benefits to be gained in this category. Similarly, trucks damage roadways faster than trains wear down tracks. Thus, the cost of per ton-mile maintenance is much higher for trucks. Furthermore, accident costs for trucks are also approximately four times higher than for rail. The close proximity of trucks to private vehicles increases the chance of collision, thereby increasing costs. However, because trains run along tracks not utilized by other vehicles, the accident cost per ton-mile is much lower. In the same vein, more trucks equals more congestion. Because highways and urban roads experience higher volumes of traffic, this congestion equates not only to slower speeds, but to longer travel times. Moreover, with the exception of railway road crossings, increased rail use is largely isolated from other transport modes. As such, the congestion cost of transporting freight by rail as opposed to truck is significantly lower.

Environmental Cost Savings from Diverting Freight from Truck to Rail

The increase in fuel expenditure from transporting intermodal freight by truck instead of rail is measured through the additional NOx, PM, VOC, and CO_2 released into the air as a result of burning more diesel fuel. Additionally, the incremental cost of noise pollution from transporting by truck compared to transporting by rail is included.

Maintenance Cost Savings from Bridge Improvements

At current conditions, the Merchants Bridge costs approximately $200,000 per year to maintain. Without improvements, this cost is expected to rise at an accelerating rate until the bridge’s closure in 2034. The cost of maintenance will rise 3% for the next three years and climb by 5% for each of the following three years as the steel fatigues. Thereafter, maintenance costs are expected to rise 25% annually until closure. In addition to the annual maintenance increases, under the no-build scenario, an $8 million floor system replacement must be carried out in 2019 in order for the Merchants Bridge to continue to operate until 2034. However, if the bridge is replaced, the maintenance cost is expected to halve to $100,000 per year during the 20 and 30 year time horizons, increasing 3% annually to account for inflation. The differential between the two maintenance costs makes up the maintenance cost savings category, which generates positive benefits until after 2034, when the bridge is no longer in commission under the no-build alternative and only the build scenario costs are accrued. The cost savings from this category are the only benefits that will be realized at the commencement of the project in 2017, rather than at its completion in December 2019.

QUANTIFYING PROJECT COSTS

The costs of reconstructing the Merchants Bridge will be experienced in the first four years of the project. Construction costs make up the bulk of the project costs. From 2017 to 2019, an estimated $150 million to $212 million will be spent rebuilding the Merchants Bridge. Table 1 details the summary of costs for the lower and upper bound estimates, holding all else equal. To prevent an over-inflation of the net benefits, the higher project cost of $212 million is used in this analysis. The costs are divided between the three years of the project, with $70 million being spent each year except in the first year, when $72 million is spent. In addition to the actual construction costs, there will also be extra costs incurred by closing the bridge and rerouting freight. Inversely to how project benefits are calculated, the project costs are measured by the additional rail ton-miles and travel hours spent as a result of the bridge closing for three weeks per year from 2017 to 2019. Without the bridge crossing during these closures, freight must be diverted to longer routes in order to cross the Mississippi River. Therefore, transportation costs, inventory costs, and environmental costs rise during these years as a result of improving the bridge.

Table 1 illustrates the total costs that will be incurred as a result of reconstructing the Merchants Bridge.

Table 1. Summary of project costs, 7% discount rate (in 2015 dollars)

Total Cost by Category (000s)					
Year	**Construction Cost**	**Transportation Cost due to Construction**	**Environmental Cost due to Construction**	**Cost of Delay due to Construction**	**Total Cost per Year due to Project**
Construction Costs: $212 Million					
2017	$72,000	$10,261	$3,722	$4,348	$90,331
2018	$65,421	$9,704	$3,331	$4,095	$82,550
2019	$61,141	$9,180	$2,985	$3,857	$77,162
				Total Cost	**$250,042**
Construction Costs: $150 Million					
2017	$50,000	$10,261	$3,722	$4,348	$68,331
2018	$46,729	$9,704	$3,331	$4,095	$63,858
2019	$43,672	$9,180	$2,985	$3,857	$59,694
				Total Cost	**$191,884**

Each value is given at the 7% discount rate for each cost category. Using the higher construction cost estimate, reconstructing the Merchants Bridge will cost approximately $250 million, approximately $58 million more than the lower cost estimate. However, compared to the benefits detailed in the following chapter, even the more conservative cost measure does not begin to offset the billions of dollars saved by the project. The following section summarizes the cost savings of the project in detail.

SUMMARY OF FINDINGS

Replacing the Merchants Bridge will generate billions of dollars in benefits over the coming decades. Table 2 details the NPV of the project over 20 and 30 year time horizons.

Table 2. Summary of project benefits (in 2015 dollars)

	Total Benefits (000s)	Total Costs (000s)	NPV (000s)	B/C Ratio
20 Year Horizon (2017-2036)				
Undiscounted	$10,184,259	$267,003	$9,917,256	38.14
3% Discount Rate	$7,310,989	$259,359	$7,051,629	28.19
7% Discount Rate	$4,926,370	$250,044	$4,676,326	19.70
30 Year Horizon (2017-2046)				
Undiscounted	$20,090,963	$267,003	$19,823,960	75.25
3% Discount Rate	$12,117,968	$259,359	$11,858,608	46.72
7% Discount Rate	$6,841,311	$250,044	$6,591,267	27.36

At the 7% discount rate, the NPV of completing the project is approximately $4.68 billion over the next 20 years and $6.59 billion over 30 years, with benefit-cost ratios of 19.70 and 27.36, respectively. The total benefits and costs are also given at the 3% discount rate, and in undiscounted values. It is important to note that these benefits will be enjoyed by both the transportation industry and the region at large.

Table 3 breaks the benefit category down into four benefit types: environmental cost savings, transportation cost savings, inventory cost savings, and bridge maintenance cost savings.

Table 3. Project cost savings by type, 7% discount rate (in 2015 dollars)

	Cost savings by type (000s)				
	Environmental	Transportation	Inventory	Bridge Maintenance	Total
20 year Horizon	$636,044	$3,102,759	$1,173,883	$13,683	$4,926,370
30 year Horizon	$796,862	$4,386,101	$1,645,026	$13,321	$6,841,311

Transportation cost savings make up the largest benefit category, with savings of over $3.1 billion from improving the bridge in the 20 year time horizon. Bridge maintenance costs make up the smallest benefit category, at only $13.7 million in the first 20 years of the project. This figure falls from the 20 year horizon to the 30 year horizon because the bridge is set to close in 2034 should the project not move forward. Figure 1 shows a pie chart comparing costs over the 20 year horizon.

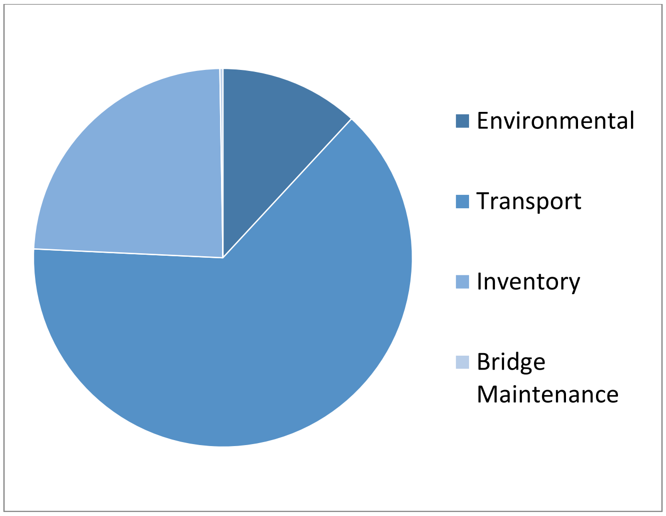

Figure 1. Components of cost savings, 20 year horizon

As shown in Figure 1, inventory cost savings is the second largest benefit category, followed by environmental cost savings as the third largest.

Livability

In terms of livability, the project will produce greater access to goods and resources as the cost of transportation decreases. By expanding the capacity of the bridge, freight will be transported more quickly and will reach consumers at lower costs. Table 4 illustrates the total hours saved by the project.

Table 4. Hours saved by project

	Diverting from Truck to Rail	Avoiding Diversion to Longer Rail Routes	Run Time Improvements	Total
20 year Horizon	2,685,023.4	4,3391,958.3	240,355.8	7,317,337.5
30 year Horizon	5,358,903.9	8,765,690.0	479,714.2	14,604,308.1

From 2017 to 2036, more than 7.3 million transportation hours will be avoided. Under the 30 year horizon, the total hours saved climbs to over 14.6 million.

Even though projected freight tonnage is expected to increase by 35% from 2010 to 2050, this will not keep pace with the forecasted increase in total demand. Freight transportation is a derived demand because as consumers desire more goods and services, transport systems will then be required to move them. As the population increases in the coming years, and as the nation's gross domestic product also rises, the derived demand for freight transport will grow. A 2007 report developed for the Association of American Railroads (AAR) suggests that demand for rail freight will increase 88% by the year 2035 (Grenzeback et al. 2007). In this way, demand will surpass the capacity of the country's aging rail infrastructure. Refurbishing the Merchants

Bridge is a crucial step towards enhancing freight capacity to accommodate this influx and help minimize transport costs.

Note that another livability benefit that would positively impact the public but is not quantified in the cost-benefit analysis is the Amtrak route between St. Louis and Chicago. Improving the Merchants Bridge will make travel between the two cities more accessible and reduce congestion along the Interstates.

Economic Competitiveness

Because the Merchants Bridge is open to all railroads, the reduced operating and travel time costs as a result of the project will be felt by the entire industry, not just a single company. The total transport hours saved, as detailed in Table 4, directly translate into operating costs saved, in addition to other benefits. If goods can arrive to the same destination in a shorter time span at a fraction of the cost, this will reduce costs to consumers, thereby increasing demand for goods, which will in turn generate more revenue for suppliers. Expanding rail capacity will also increase the reliability of the shipments because they will be less likely to bottleneck on either side of the Mississippi River due to weight restrictions and congestion. Table 5 details the total transportation cost savings gained by the project.

Table 5. Transportation cost savings, 7% discount rate (in 2015 dollars)

	Cost savings by type (000s)			
	Diverting Intermodal Freight from Truck to Rail	**Avoiding Diversion to Longer Rail Routes**	**Run Time Improvements**	**Total**
20 year Horizon	$351,857	$2,701,304	$49,598	$3,102,759
30 year Horizon	$495,758	$3,820,157	$70,186	$4,386,101

After the first 20 years of the project, improving the Merchants Bridge will generate approximately $3.1 billion in transportation cost savings. When looking at the 30 year horizon, this figure rises to nearly $4.4 billion. Table 6 breaks down transportation costs even farther into individual components.

Table 6. Components of transportation cost savings, 7% discount rate (in 2015 dollars)

Cost savings by type (000s)		
	20 year Horizon	**30 year Horizon**
Fuel	$1,371,628	$1,960,173
Labor	$236,771	$331,800
Maintenance	$328,683	$460,601
Congestion	$113,621	$159,223
Accident	$447,801	$627,528
Railcar	$154,915	$217,090
Locomotive	$449,341	$629,686
Total	$3,102,759	$4,386,101

Figure 2 illustrates how much each component represents within the total.

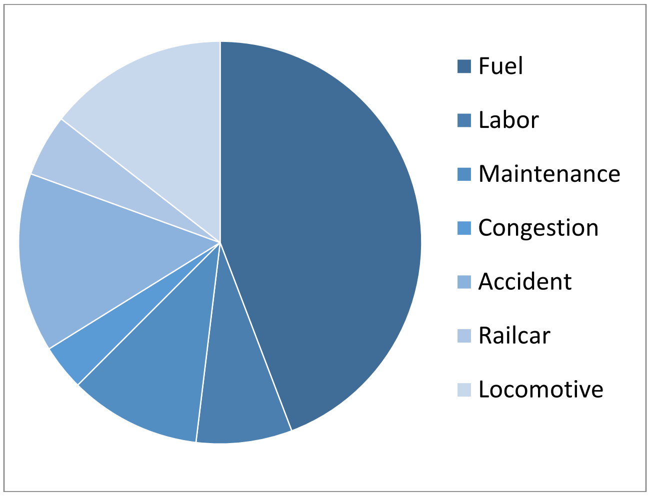

Figure 2. Components of transportation cost savings, 20 year horizon

As can be observed from Figure 2, fuel makes up the largest portion of the whole cost savings, at nearly $1.35 billion in savings from 2017 to 2036. In the 30 year horizon, this increases to over $1.9 billion in fuel savings.

Other sizeable components of transportation cost savings are accident costs and the cost of locomotive use. Here, accident cost savings are almost $448 million in the first 20 years. Locomotive cost savings are only marginally higher, at $449 million. The smallest component of accident cost savings is congestion costs, at $113.6 million by 2036. However, although the congestion cost savings are the smallest out of the total, this figure almost exclusively impacts the public. Thus, the $113.6 million reduction in congestion means that the public will enjoy considerably fewer trucks on the roadways compared to the no-build alternative.

Inventory cost savings are another area that improve economic competitiveness. Considering that the demand for freight outstrips freight supply, efficiency is integral to keeping up with the growing demand. Therefore, running freight along longer routes equals a foregone opportunity. In this way, the inventory cost savings for the Merchants Bridge project are measured as the opportunity cost of delayed lading. By avoiding longer routes or increasing travel speeds, these delayed lading costs can be lessened.

Table 7 details the total savings in inventory costs gained by improving the Merchants Bridge.

Table 7. Inventory cost savings, 7% discount rate (in 2015 dollars)

	Inventory cost savings by type (000s)		
	Avoiding diversion to longer rail routes	**Run time improvements**	**Total**
20 year horizon	$1,112,974	$60,909	$1,173,883
30 year horizon	$1,559,671	$85,355	$1,645,026

In the first 20 years of the project, the over 7.3 million hours saved equates to over $1.15 billion in benefits. Over the course of 30 years, this figure climbs to almost $1.62 billion. Minimizing the costs of delayed lading will benefit both the supplier and the consumer. Not only will the consumer be able to access goods more quickly at a lower cost, suppliers will also experience higher profits as a result of being able to distribute more merchandise within the same timeframe.

Safety

As freight is taken off the roadways and is instead transported across rail lines, public safety will increase in step. Per ton-mile, the accident cost of transporting by truck is more than four times that of rail transport. This is largely due to the close proximity of freight trucks to other noncommercial vehicles. More trucks on the road increases the likelihood of accident and injury. In contrast, apart from railway crossings, trains have fewer opportunities to come into contact with other vehicles. In addition, by avoiding diversion to longer rail routes, this will also equate to higher levels of safety as fewer miles are traveled per ton. In total, the accident costs saved due to the project in its first 20 years are approximately $447.8 million, and the cost savings are over $627.5 million after 30 years. Table 8 outlines total accident cost savings as a result of the project.

Table 8. Accident cost savings, 7% discount rate (in 2015 dollars)

	Accident cost savings by type (000s)		
	Diverting Intermodal Freight from Truck to Rail	**Avoiding Diversion to Longer Rail Routes**	**Total**
20 year Horizon	$11,265	$436,536	$447,801
30 year Horizon	$15,786	$611,742	$627,528

Accident cost savings from run time improvements are not included in this measurement because they do not translate into a change in ton-miles traveled.

State of Good Repair

Replacing the Merchants Bridge will also generate state of good repair benefits in several ways. For instance, maintenance costs will reduce. For every ton-mile freight is transported across rail or road, a maintenance cost is associated with that action, and the cost is considerably steeper for road than for rail. Therefore, since building the bridge will incentivize the diversion of freight from the highways to the railways, ton for ton, rail freight will cause less damage on the nation's transportation infrastructures. Table 9 outlines the total maintenance cost savings for both time horizons.

Table 9. Maintenance cost savings, 7% discount rate (in 2015 dollars)

Road and Railway Maintenance Savings (000s)			
	Diverting Intermodal Freight from Truck to Rail	**Avoiding Diversion to Longer Rail Routes**	**Total**
20 year Horizon	$223,985	$104,698	$328,683
30 year Horizon	$313,882	$146,720	$460,601

Merchants Bridge Maintenance Savings (000s)			
	Baseline Alternative	**Build Alternative**	**Cost Savings**
20 year Horizon	$14,724	$1,041	$13,683
2020 to 2034	$7,124	$951	$6,173

Almost $323 million will be saved in the first 20 years, and greater than $453 million will be saved with an additional 10 years.

The second state of good repair benefit comes from the maintenance cost reduction in the bridge itself, also included in Table 9. Fixing the bridge now will reduce long term repairs in the future. Currently, the Merchants Bridge costs approximately $200,000 annually to maintain. This figure is expected to rise in the coming years as age and use will cause the structural integrity of the bridge to further deteriorate. Including the $8 million floor replacement in 2019, under the baseline scenario, the projected maintenance costs for the 20 year horizon are $14.7 million at the 7% discount rate. However, in the build alternative, maintenance costs are expected to be around $100,000 annually. Accounting for a 3% increase in costs due to inflation, at the 7% discount rate, this amounts to only $1 million over the 20 year horizon.

Rather than simply looking at the period from 2017 to 2036, perhaps a better way of comparing the costs is to compare the time period when the bridge will be open under both alternatives. For the build alternative, construction is set to conclude December 2019. Therefore, the annual maintenance costs under the build alternative are adjusted to begin in January 2020. Similarly, the baseline alternative has the bridge closing in 2034, so no further maintenance costs will be incurred after that time period. Thus, the cost differential between the two alternatives for the period beginning January 2020 and lasting to the end of 2034 shows that $6.17 million dollars will be saved in bridge maintenance costs under the build alternative.

Sustainability

Finally, the reduction in miles traveled will also result in fewer gallons of fuel burned. In this way, the project will generate sustainability benefits that can be quantified in terms of a reduction of pollutant emissions. As less fuel is burned, fewer pollutants will be released into the air, which will in turn improve the overall air quality. The key feature of this benefit is that it can be enjoyed by everyone. Each pollutant (NOx, PM, VOC, and CO_2) is associated with a cost per ton, and as the total gallons of diesel fuel consumed decreases as a result of the project, this environmental cost will fall.

Moreover, a reduction in noise pollution is also a contributor to sustainability. Fewer rail and truck miles traveled will produce less noise that can negatively impact the public. Therefore, decreasing the amount of noise produced per ton-mile of freight transported will generate positive impacts for the overall sustainability of the region. Table 10 illustrates the environmental cost savings that would be enjoyed as a result of improving the Merchants Bridge.

In the first 20 years of the project, $636 million dollars in environmental costs will be saved. After 30 years, this increases to almost $797 million in realized environmental cost savings. Figure 3 illustrates how the five categories contribute to total environmental cost savings.

Table 10. Environmental cost savings, 7% discount rate (in 2015 dollars)

	Environmental cost savings(000s)			
	Diverting Intermodal Freight from Truck to Rail	**Avoiding Diversion to Longer Rail Routes**	**Run Time Improvements**	**Total**
NO_X				
20 year Horizon	$2,979	$175,199	$975	$179,153
30 year Horizon	$3,475	$198,872	$1,128	$203,475
PM				
20 year Horizon	$2,927	$172,921	$959	$176,806
30 year Horizon	$3,268	$189,290	$1,064	$193,622
VOC				
20 year Horizon	$27	$1,582	$9	$1,618
30 year Horizon	$31	$1,796	$10	$1,838
CO_2				
20 year Horizon	$13	$177,156	$1,005	$178,174
30 year Horizon	$20	$255,844	$1,518	$257,382
Noise				
20 year Horizon	$6,661	$93,631	N/A	$100,292
30 year Horizon	$9,334	$131,211	N/A	$140,545
Total Environmental Cost Savings			20 year Horizon	$636,044
			30 year Horizon	$796,862

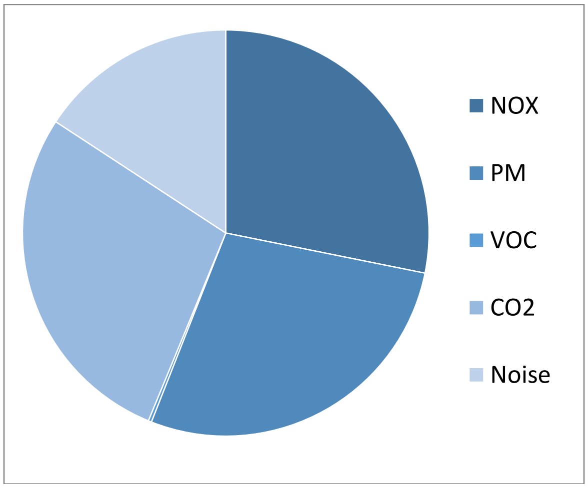

Figure 3. Components of environmental cost savings, 20 year horizon

VOC is the smallest cost by a significant margin, making up just a sliver of the total with only $1.6 million in savings in the first 20 years. In contrast, NOx composes the largest portion, at greater than $179 million in the 20 year horizon. CO_2 and PM are also large contributors, at approximately $178 million and $177 million in savings, respectively. Because noise pollution is derived from the difference in ton-miles traveled between truck and rail transport, any potential change in noise as a result of run time improvements cannot be calculated. It is important to note that this benefit category directly impacts air quality, and thus cost savings are experienced by the general public.

CONCLUSION

The $4.7 billion dollars in benefits that would be gained in the 20 year horizon would be shared by consumers and suppliers alike. However, perhaps a better way of measuring benefits is to look at the horizon that occurs after the bridge would otherwise close. The 30 year horizon forecasts that approximately $6.6 billion dollars will be saved if the bridge is constructed. These benefits would only continue to increase in the future if the Merchants Bridge is improved. As demand for freight rises, the nation's current rail infrastructure will not be able to accommodate an increase in freight traffic if half of the most heavily utilized Mississippi River crossing is out of service. Because it is cheaper to repair an existing bridge than to build a completely new bridge, savings will be greater if the Merchants Bridge project moves forward. Time is also a consideration. Completing the improvements now will not only increase freight capacity by restoring the Merchants Bridge to a double-track bridge, it will also alleviate the traffic burden the MacArthur Bridge now carries.

As the MacArthur Bridge continues to age, it too will require weight restrictions and face closure if repairs are not eventually made. Improving the Merchants Bridge now will postpone the need for MacArthur Bridge repairs and will also allow the Merchants Bridge to be able to accommodate the extra burden of freight while a MacArthur Bridge project goes forward. If closing one half of the most heavily used Mississippi River crossing amounts to $6.6 billion in losses for the transport industry and the public over the next 30 years, the potential closing of the other half would more than double these losses. Without the Merchants-MacArthur Bridge crossing, trains would have to be rerouted hundreds of miles because few Mississippi River bridges are open to all railroad companies. Such a situation would cause significant increases in costs and congestion and would cripple the current freight rail system. Therefore, improving the Merchants Bridge now will generate billions of dollars in benefits and will protect the longevity of the most heavily utilized Mississippi River crossing in the country.

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APPENDIX A. TOTAL ANNUAL BENEFITS

Table A-1. Annual undiscounted benefits by category (in 2015 dollars)

	Total Transportation Cost Savings due to diverting intermodal freight from truck to rail	Total environmental savings due to diversion of intermodal freight from truck to rail	Total Transportation Cost Savings by not diverting Freight to longer rail routes	Total Environmental Savings by not diverting Freight to longer rail routes	Total Inventory Cost Savings by not diverting freight to longer rail routes	Total transportation cost savings due to run time improvements	Total Environmental savings due to run time improvements	Total Inventory cost savings due to run time improvements	Total Maintenance Cost Savings due to Bridge Improvement
2017	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$212,180.00
2018	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$218,545.40
2019	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$8,225,101.76
2020	$37,154,951.57	$1,653,524.75	$282,466,949.62	$87,461,273.81	$118,556,214.11	$5,198,828.79	$408,473.83	$6,488,148.46	$131,854.81
2021	$37,499,052.13	$1,625,779.50	$286,089,558.41	$84,936,714.03	$119,480,952.58	$5,254,317.34	$398,743.00	$6,538,756.01	$163,633.03
2022	$37,853,235.44	$1,575,536.05	$290,121,123.13	$81,096,152.70	$120,412,904.01	$5,312,572.26	$381,692.50	$6,589,758.31	$200,537.99
2023	$38,189,389.71	$1,545,602.97	$292,833,659.26	$78,598,706.37	$121,352,124.66	$5,364,277.47	$371,550.48	$6,641,158.43	$243,349.49
2024	$38,530,833.44	$1,492,628.90	$295,678,403.56	$74,791,227.61	$122,298,671.23	$5,417,185.61	$353,972.15	$6,692,959.46	$292,964.64
2025	$38,879,682.24	$1,460,485.02	$298,773,396.29	$72,692,273.61	$123,252,600.86	$5,471,976.66	$345,467.96	$6,745,164.55	$350,415.44
2026	$39,225,539.38	$1,427,408.93	$301,500,938.27	$69,869,446.66	$124,213,971.15	$5,525,237.98	$332,699.28	$6,797,776.83	$463,523.33
2027	$39,574,332.62	$1,398,215.28	$304,215,398.73	$67,709,756.91	$125,182,840.13	$5,578,915.77	$323,384.34	$6,850,799.49	$605,673.31
2028	$39,927,609.60	$1,368,112.14	$307,003,631.40	$65,560,605.47	$126,159,266.28	$5,633,507.69	$313,903.84	$6,904,235.72	$784,148.86
2029	$40,282,797.92	$1,313,827.56	$309,717,488.52	$62,122,182.41	$127,143,308.56	$5,688,175.37	$296,755.34	$6,958,088.76	$1,008,055.02
2030	$40,639,115.42	$1,281,736.31	$312,315,562.14	$60,004,214.61	$128,135,026.36	$5,742,668.27	$286,921.31	$7,012,361.86	$1,288,773.78
2031	$40,997,273.82	$1,272,512.09	$314,839,962.72	$59,190,526.63	$129,134,479.57	$5,797,217.64	$284,533.71	$7,067,058.28	$1,640,533.39
2032	$41,366,489.84	$1,244,101.96	$317,786,544.23	$57,374,186.82	$130,141,728.51	$5,854,762.79	$276,101.76	$7,122,181.33	$2,081,119.88
2033	$41,747,700.44	$1,214,856.55	$321,186,398.07	$55,566,918.49	$131,156,833.99	$5,915,569.99	$267,520.96	$7,177,734.35	$2,632,766.59
2034	$42,135,954.48	$1,184,766.79	$324,761,435.23	$53,768,698.33	$132,179,857.30	$5,978,038.53	$258,789.50	$7,233,720.67	$3,323,265.97
2035	$70,109,680.72	$1,943,145.03	$541,748,085.68	$87,802,976.51	$219,571,619.86	$9,960,980.18	$424,944.82	$12,016,352.56	-$155,796.74
2036	$70,780,276.81	$1,900,316.83	$548,548,872.17	$85,327,342.47	$221,284,278.50	$10,071,671.77	$413,018.21	$12,110,080.11	-$160,470.64
2037	$71,449,587.64	$1,898,779.84	$554,941,252.01	$85,587,447.06	$223,010,295.87	$10,180,970.92	$417,908.65	$12,204,538.73	-$165,284.76
2038	$72,098,840.45	$1,853,959.36	$560,010,919.97	$83,130,978.52	$224,749,776.18	$10,283,035.42	$405,688.47	$12,299,734.13	-$170,243.31

	Total Transportation Cost Savings due to diverting intermodal freight from truck to rail	Total environmental savings due to diversion of intermodal freight from truck to rail	Total Transportation Cost Savings by not diverting Freight to longer rail routes	Total Environmental Savings by not diverting Freight to longer rail routes	Total Inventory Cost Savings by not diverting freight to longer rail routes	Total transportation cost savings due to run time improvements	Total Environmental savings due to run time improvements	Total Inventory cost savings due to run time improvements	Total Maintenance Cost Savings due to Bridge Improvement
2039	$72,780,998.11	$1,851,314.77	$566,390,321.93	$82,804,642.15	$226,502,824.43	$10,394,418.72	$406,763.09	$12,395,672.06	-$175,350.61
2040	$73,464,884.62	$1,814,007.22	$572,525,117.15	$80,827,918.52	$228,269,546.46	$10,505,363.65	$397,173.72	$12,492,358.30	-$180,611.12
2041	$74,125,892.38	$1,799,012.69	$577,254,022.31	$79,971,523.99	$230,050,048.92	$10,608,272.30	$394,635.14	$12,589,798.70	-$186,029.46
2042	$74,793,735.87	$1,785,632.61	$582,022,102.04	$79,222,373.39	$231,844,439.31	$10,712,379.63	$392,702.29	$12,687,999.13	-$191,610.34
2043	$75,468,500.30	$1,773,721.43	$586,829,681.82	$77,984,680.12	$233,652,825.93	$10,817,702.44	$387,437.22	$12,786,965.52	-$197,358.65
2044	$76,150,272.12	$1,763,298.00	$591,677,089.83	$77,427,947.73	$235,475,317.97	$10,924,257.84	$386,586.65	$12,886,703.85	-$203,279.41
2045	$76,839,139.12	$1,754,228.55	$596,564,656.98	$76,956,214.30	$237,312,025.46	$11,032,063.22	$386,247.32	$12,987,220.14	-$209,377.79
2046	$77,535,190.35	$1,746,436.92	$601,492,716.94	$76,563,158.20	$239,163,059.25	$11,141,136.22	$386,392.04	$13,088,520.46	-$215,659.13

Table A-2. Annual benefits by category, 3% discount rate (in 2015 dollars)

	Total Transportation Cost Savings due to diverting intermodal freight from truck to rail	Total environmental savings due to diversion of intermodal freight from truck to rail	Total Transportation Cost Savings by not diverting Freight to longer rail routes	Total Environmental Savings by not diverting Freight to longer rail routes	Total Inventory Cost Savings by not diverting freight to longer rail routes	Total transportation cost savings due to run time improvements	Total Environmental savings due to run time improvements	Total Inventory cost savings due to run time improvements	Total Maintenance Cost Savings due to Bridge improvement
2017	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$212,180.00
2018	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$212,180.00
2019	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$7,752,947.27
2020	$34,002,044.04	$1,513,209.38	$258,497,272.99	$80,039,455.24	$108,495,730.50	$4,757,664.80	$373,811.42	$5,937,574.94	$120,665.83
2021	$33,317,422.13	$1,444,484.03	$254,186,867.19	$75,465,170.31	$106,157,278.84	$4,668,392.90	$354,277.99	$5,809,600.03	$145,385.83
2022	$32,652,533.41	$1,359,071.24	$250,261,029.35	$69,954,253.70	$103,869,228.75	$4,582,671.50	$329,251.30	$5,684,383.41	$172,985.83
2023	$31,983,012.65	$1,294,418.16	$245,243,579.46	$65,825,179.18	$101,630,493.92	$4,492,497.93	$311,167.68	$5,561,865.63	$203,801.37
2024	$31,329,093.59	$1,213,643.89	$240,413,600.02	$60,812,112.30	$99,440,011.43	$4,404,667.64	$287,811.75	$5,441,988.52	$238,207.06

	Total Transportation Cost Savings due to diverting intermodal freight from truck to rail	Total environmental savings due to diversion of intermodal freight from truck to rail	Total Transportation Cost Savings by not diverting Freight to longer rail routes	Total Environmental Savings by not diverting Freight to longer rail routes	Total Inventory Cost Savings by not diverting freight to longer rail routes	Total transportation cost savings due to run time improvements	Total Environmental savings due to run time improvements	Total Inventory cost savings due to run time improvements	Total Maintenance Cost Savings due to Bridge improvement
2025	$30,691,980.19	$1,152,920.37	$235,854,478.00	$57,383,952.05	$97,296,741.28	$4,319,628.91	$272,715.60	$5,324,695.18	$276,621.18
2026	$30,063,109.72	$1,093,990.09	$231,075,363.91	$53,549,113.00	$95,199,665.88	$4,234,634.84	$254,986.29	$5,209,929.90	$355,252.03
2027	$29,447,020.09	$1,040,403.48	$226,364,827.01	$50,382,418.09	$93,147,789.59	$4,151,237.27	$240,628.32	$5,097,638.21	$450,677.82
2028	$28,844,554.70	$988,353.32	$221,785,955.32	$47,362,376.30	$91,140,138.20	$4,069,765.82	$226,770.81	$4,987,766.79	$566,485.82
2029	$28,253,543.98	$921,492.22	$217,229,614.99	$43,571,248.86	$89,175,758.52	$3,989,571.76	$208,138.22	$4,880,263.46	$707,029.51
2030	$27,673,260.10	$872,800.06	$212,671,700.54	$40,859,950.34	$87,253,717.90	$3,910,477.66	$195,379.45	$4,775,077.20	$877,592.23
2031	$27,104,027.71	$841,280.40	$208,146,305.34	$39,131,911.09	$85,373,103.79	$3,832,643.81	$188,110.30	$4,672,158.06	$1,084,585.83
2032	$26,551,575.72	$798,541.70	$203,975,090.13	$36,826,307.28	$83,533,023.30	$3,757,949.45	$177,219.21	$4,571,457.18	$1,335,791.66
2033	$26,015,786.70	$757,058.44	$200,152,744.60	$34,627,466.51	$81,732,602.80	$3,686,387.65	$166,710.22	$4,472,926.74	$1,640,653.09
2034	$25,492,945.42	$716,803.39	$196,486,009.29	$32,530,946.76	$79,970,987.47	$3,616,811.62	$156,571.91	$4,376,519.97	$2,010,630.57
2035	$41,182,048.40	$1,141,392.91	$318,219,904.22	$51,574,994.93	$128,975,185.49	$5,851,026.05	$249,610.30	$7,058,340.69	-$91,514.17
2036	$40,365,002.84	$1,083,724.13	$312,829,756.82	$48,660,991.12	$126,195,331.98	$5,743,733.68	$235,538.51	$6,906,209.47	-$91,514.17
2037	$39,559,904.33	$1,051,308.36	$307,257,516.23	$47,387,694.30	$123,475,393.76	$5,636,956.75	$231,385.89	$6,757,357.19	-$91,514.17
2038	$38,756,679.48	$996,594.51	$301,033,464.53	$44,686,997.31	$120,814,079.44	$5,527,638.25	$218,077.54	$6,611,713.18	-$91,514.17
2039	$37,983,857.12	$966,187.29	$295,594,861.59	$43,215,121.78	$118,210,125.50	$5,424,769.18	$212,286.61	$6,469,208.29	-$91,514.17
2040	$37,224,050.84	$919,142.49	$290,093,752.63	$40,954,839.36	$115,662,295.61	$5,322,981.07	$201,244.65	$6,329,774.87	-$91,514.17
2041	$36,465,027.20	$884,995.03	$283,970,728.01	$39,340,690.60	$113,169,380.11	$5,218,567.03	$194,134.34	$6,193,346.71	-$91,514.17
2042	$35,721,904.80	$852,828.08	$277,976,997.37	$37,837,046.74	$110,730,195.41	$5,116,292.17	$187,556.80	$6,059,859.05	-$91,514.17
2043	$34,994,345.67	$822,465.28	$272,109,829.36	$36,161,084.99	$108,343,583.44	$5,016,111.58	$179,652.60	$5,929,248.49	-$91,514.17
2044	$34,282,019.10	$793,817.46	$266,366,550.39	$34,857,214.68	$106,008,411.06	$4,917,981.32	$174,037.08	$5,801,453.04	-$91,514.17
2045	$33,584,601.44	$766,732.52	$260,744,543.33	$33,635,772.28	$103,723,569.57	$4,821,858.37	$168,819.72	$5,676,412.01	-$91,514.17
2046	$32,901,775.97	$741,094.15	$255,241,246.39	$32,489,297.67	$101,487,974.19	$4,727,700.63	$163,964.06	$5,554,066.04	-$91,514.17

Table A-3. Annual benefits by category, 7% discount rate (in 2015 dollars)

	Total Transportation Cost Savings due to diverting intermodal freight from truck to rail	Total environmental savings due to diversion of intermodal freight from truck to rail	Total Transportation Cost Savings by not diverting Freight to longer rail routes	Total Environmental Savings by not diverting Freight to longer rail routes	Total delay Cost Savings by not diverting freight to longer rail routes	Total transportation cost savings due to run time improvements	Total Environmental savings due to run time improvements	Total delay cost savings due to run time improvements	Total Maintenance Cost Savings due to Bridge Improvement
2017	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$212,180.00
2018	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$204,248.04
2019	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$7,184,122.42
2020	$30,329,508.09	$1,349,768.74	$230,577,171.27	$71,394,452.12	$96,777,185.87	$4,243,792.90	$333,436.32	$5,296,261.81	$107,632.80
2021	$28,607,847.33	$1,240,299.39	$218,256,354.33	$64,797,812.46	$91,151,446.65	$4,008,493.54	$304,199.12	$4,988,385.66	$124,834.86
2022	$26,988,833.72	$1,123,335.43	$206,852,351.17	$57,820,436.09	$85,852,736.39	$3,787,790.60	$272,141.48	$4,698,406.60	$142,980.82
2023	$25,447,202.86	$1,029,900.52	$195,127,431.72	$52,373,636.79	$80,862,044.61	$3,574,444.58	$247,579.77	$4,425,284.27	$162,154.04
2024	$23,995,066.58	$929,534.26	$184,133,649.50	$46,576,217.69	$76,161,465.94	$3,373,550.94	$220,436.06	$4,168,038.78	$182,443.65
2025	$22,628,329.05	$850,015.58	$173,888,836.84	$42,307,565.07	$71,734,135.86	$3,184,740.24	$201,065.50	$3,925,747.18	$203,944.97
2026	$21,336,094.44	$776,415.88	$163,996,533.75	$38,004,349.62	$67,564,170.21	$3,005,363.37	$180,966.36	$3,697,540.19	$252,125.98
2027	$20,117,583.97	$710,781.75	$154,647,682.60	$34,420,206.99	$63,636,608.17	$2,836,037.88	$164,392.20	$3,482,599.07	$307,893.60
2028	$18,969,319.70	$649,980.22	$145,855,213.75	$31,147,371.39	$59,937,358.61	$2,676,438.92	$149,133.45	$3,280,152.66	$372,543.47
2029	$17,886,044.03	$583,355.15	$137,518,268.89	$27,582,991.92	$56,453,149.54	$2,525,617.89	$131,762.92	$3,089,474.62	$447,588.48
2030	$16,863,788.09	$531,875.00	$129,599,854.81	$24,899,615.79	$53,171,480.47	$2,383,003.17	$119,062.14	$2,909,880.87	$534,795.30
2031	$15,899,449.62	$493,502.13	$122,100,365.70	$22,955,106.73	$50,080,577.59	$2,248,260.95	$110,347.08	$2,740,727.04	$636,227.13
2032	$14,993,119.59	$450,919.80	$115,180,468.05	$20,795,045.64	$47,169,351.49	$2,122,035.47	$100,071.98	$2,581,406.28	$754,293.62
2033	$14,141,390.52	$411,513.95	$108,796,945.37	$18,822,437.78	$44,427,357.41	$2,003,808.22	$90,618.61	$2,431,346.96	$891,809.13
2034	$13,339,164.11	$375,066.82	$102,811,153.40	$17,021,792.90	$41,844,757.76	$1,892,493.90	$81,926.13	$2,290,010.71	$1,052,060.90
2035	$20,742,924.71	$574,906.50	$160,283,710.29	$25,977,732.49	$64,963,319.37	$2,947,094.61	$125,725.84	$3,555,205.13	-$46,094.63
2036	$19,571,336.35	$525,453.44	$151,678,334.22	$23,593,721.23	$61,186,946.97	$2,784,901.17	$114,202.98	$3,348,538.06	-$44,371.47
2037	$18,463,931.19	$490,680.79	$143,407,364.96	$22,117,422.72	$57,630,098.28	$2,630,956.35	$107,995.54	$3,153,884.73	-$42,712.72
2038	$17,412,813.51	$447,755.45	$135,249,965.89	$20,077,219.23	$54,280,012.19	$2,483,487.63	$97,979.07	$2,970,546.76	-$41,115.99
2039	$16,427,629.45	$417,866.12	$127,841,752.29	$18,690,097.87	$51,124,669.42	$2,346,157.15	$91,811.78	$2,797,866.38	-$39,578.94

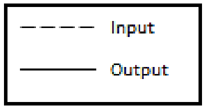
	Total Transportation Cost Savings due to diverting intermodal freight from truck to rail	Total environmental savings due to diversion of intermodal freight from truck to rail	Total Transportation Cost Savings by not diverting Freight to longer rail routes	Total Environmental Savings by not diverting Freight to longer rail routes	Total delay Cost Savings by not diverting freight to longer rail routes	Total transportation cost savings due to run time improvements	Total Environmental savings due to run time improvements	Total delay cost savings due to run time improvements	Total Maintenance Cost Savings due to Bridge Improvement
2040	$15,497,188.45	$382,659.17	$120,772,389.10	$17,050,397.50	$48,152,749.39	$2,216,073.72	$83,782.56	$2,635,224.05	-$38,099.35
2041	$14,613,669.13	$354,669.27	$113,803,679.35	$15,766,115.65	$45,353,589.56	$2,091,385.03	$77,800.98	$2,482,036.26	-$36,675.08
2042	$13,780,684.32	$329,001.34	$107,237,093.60	$14,596,657.14	$42,717,147.26	$1,973,747.14	$72,355.07	$2,337,753.40	-$35,304.05
2043	$12,995,335.62	$305,426.84	$101,049,426.37	$13,428,610.44	$40,233,963.55	$1,862,759.60	$66,714.94	$2,201,857.83	-$33,984.27
2044	$12,254,891.26	$283,768.19	$95,218,811.39	$12,460,508.07	$37,895,129.41	$1,758,044.83	$62,213.53	$2,073,861.98	-$32,713.83
2045	$11,556,776.52	$263,839.86	$89,724,644.27	$11,574,384.89	$35,692,253.66	$1,659,246.72	$58,092.45	$1,953,306.64	-$31,490.88
2046	$10,898,564.64	$245,484.09	$84,547,509.71	$10,761,933.07	$33,617,432.94	$1,566,029.47	$54,312.35	$1,839,759.28	-$30,313.65

Table A-4. Total annual benefits by discount rate (in 2015 dollars)

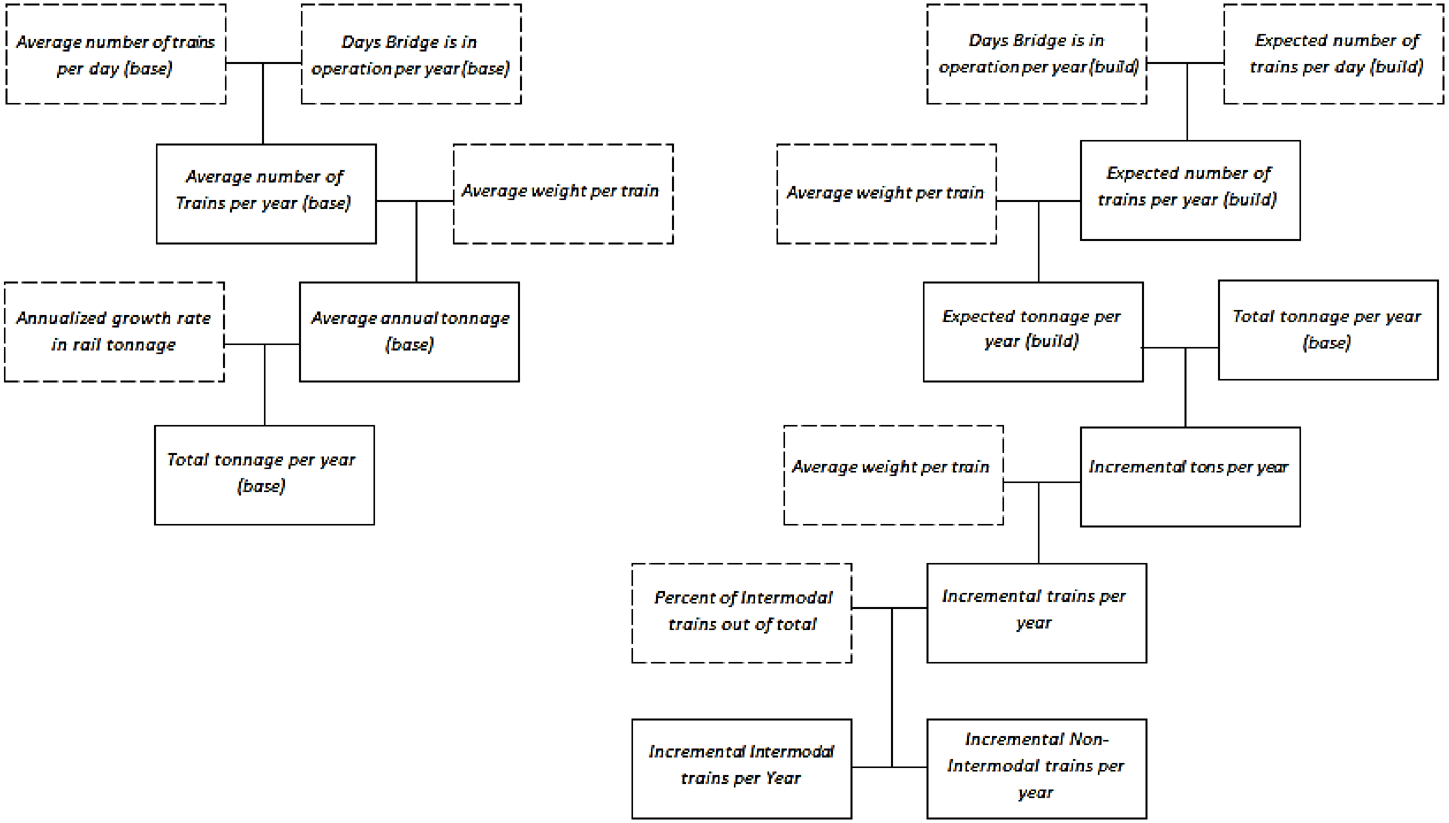
	Undiscounted	3% Discount Rate	7% Discount Rate
2017	$212,180.00	$212,180.00	$212,180.00
2018	$218,545.40	$212,180.00	$204,248.04
2019	$8,225,101.76	$7,752,947.27	$7,184,122.42
2020	$539,520,219.75	$493,737,429.16	$440,409,209.92
2021	$541,987,506.02	$481,548,879.23	$413,479,673.33
2022	$543,543,512.40	$468,865,408.49	$387,539,012.29
2023	$545,139,818.83	$456,546,015.96	$363,249,679.17
2024	$545,548,846.60	$443,581,136.19	$339,740,403.40
2025	$547,971,462.63	$432,573,732.74	$318,924,380.29
2026	$549,356,541.81	$421,036,045.66	$298,813,559.80
2027	$551,439,316.56	$410,322,639.89	$280,323,786.23
2028	$553,655,021.01	$399,972,167.07	$263,037,512.17
2029	$554,530,679.45	$388,936,661.52	$246,218,253.44
2030	$556,706,380.05	$379,089,955.48	$231,013,355.64
2031	$560,224,097.84	$370,374,126.33	$217,264,563.98
2032	$563,247,217.11	$361,526,955.64	$204,146,711.92
2033	$566,866,299.42	$353,252,336.76	$192,017,227.94
2034	$570,824,526.80	$345,358,226.41	$180,708,426.63
2035	$943,421,988.62	$554,160,988.82	$279,124,524.30
2036	$950,275,386.22	$541,928,774.38	$262,759,062.94
2037	$959,525,495.97	$531,266,002.64	$247,959,621.84
2038	$964,662,689.20	$518,553,730.08	$232,978,663.73
2039	$973,351,604.64	$507,984,903.18	$219,698,271.52
2040	$980,115,758.52	$496,616,567.35	$206,752,364.58
2041	$986,607,176.97	$485,345,354.87	$194,506,270.16
2042	$993,269,753.92	$474,391,166.25	$183,009,135.22
2043	$999,504,156.14	$463,464,807.25	$172,110,110.93
2044	$1,006,488,194.59	$453,109,969.96	$161,974,514.84
2045	$1,013,622,417.29	$443,030,795.09	$152,451,054.13
2046	$1,020,900,951.25	$433,215,604.93	$143,500,711.91

APPENDIX B. LOGIC STRUCTURE FOR COST-BENEFIT MODEL

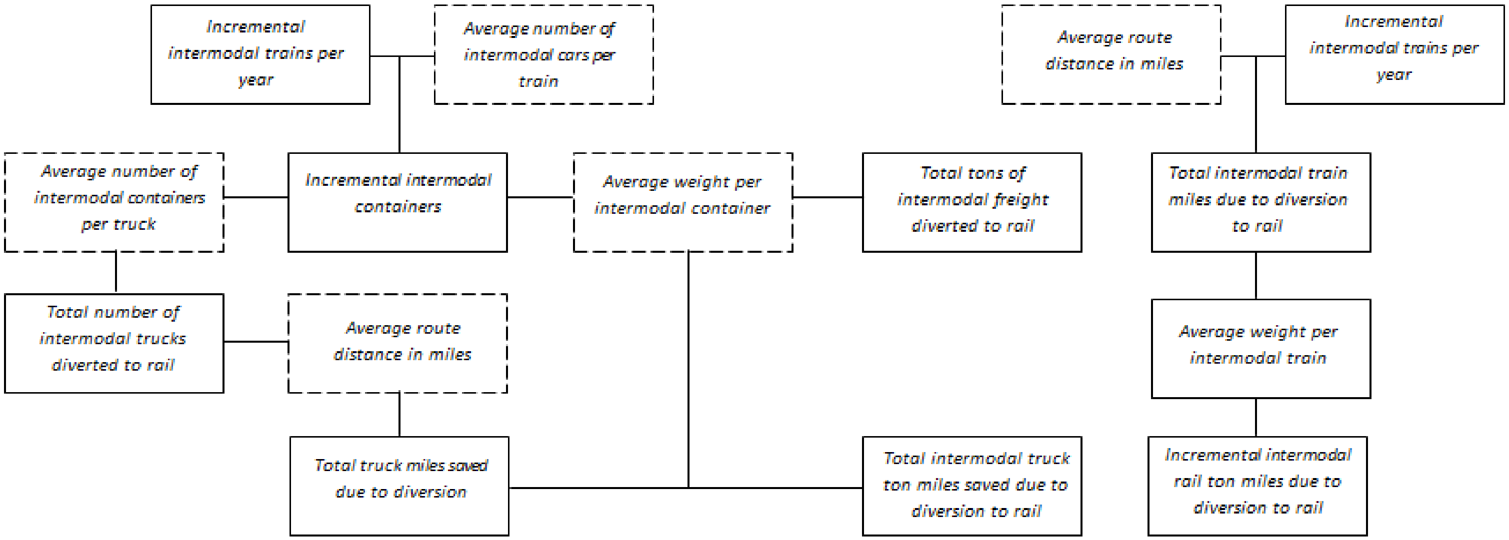
The following charts detail the logic structure for each calculation in the cost-benefit model. All structures follow the same legend:



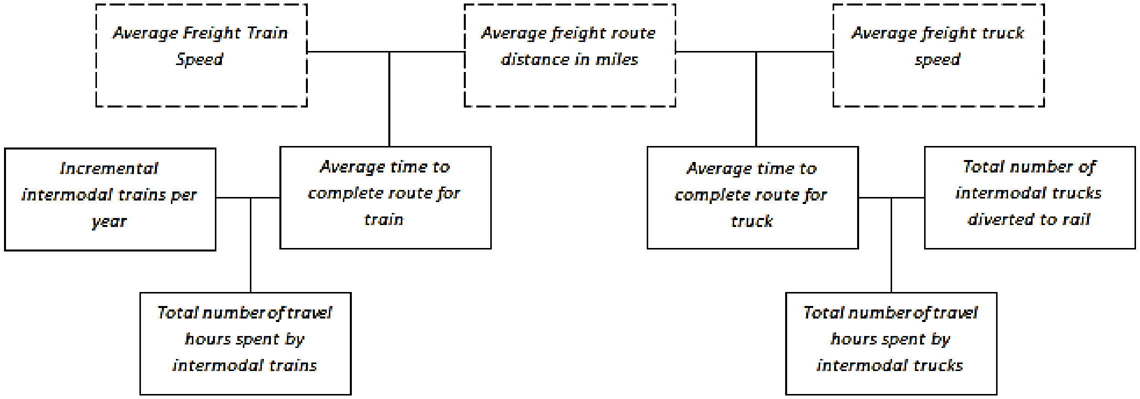
Incremental Change in Bridge Usage from Project



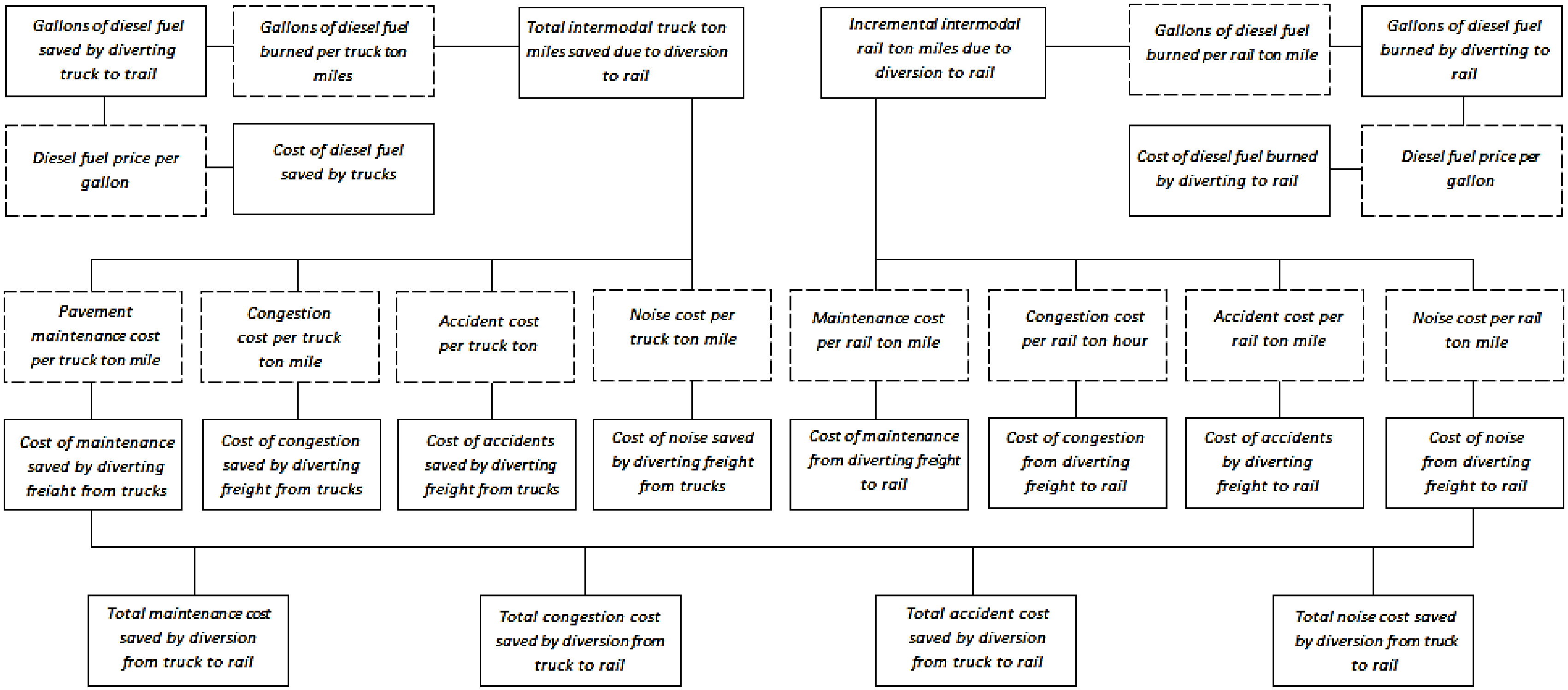
Intermodal Miles Saved by Diverting Freight from Truck to Rail



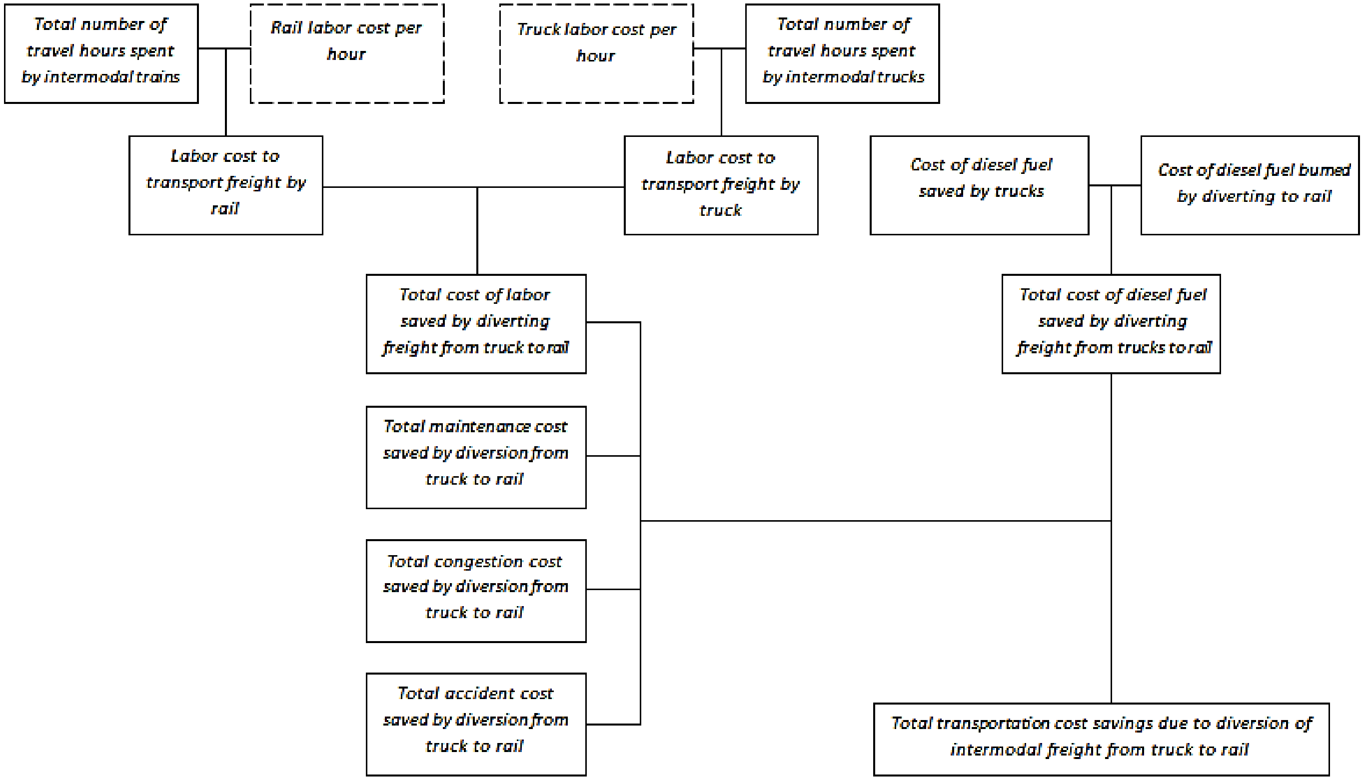
Total Hours Spent for Transporting Intermodal Freight by Rail or Truck



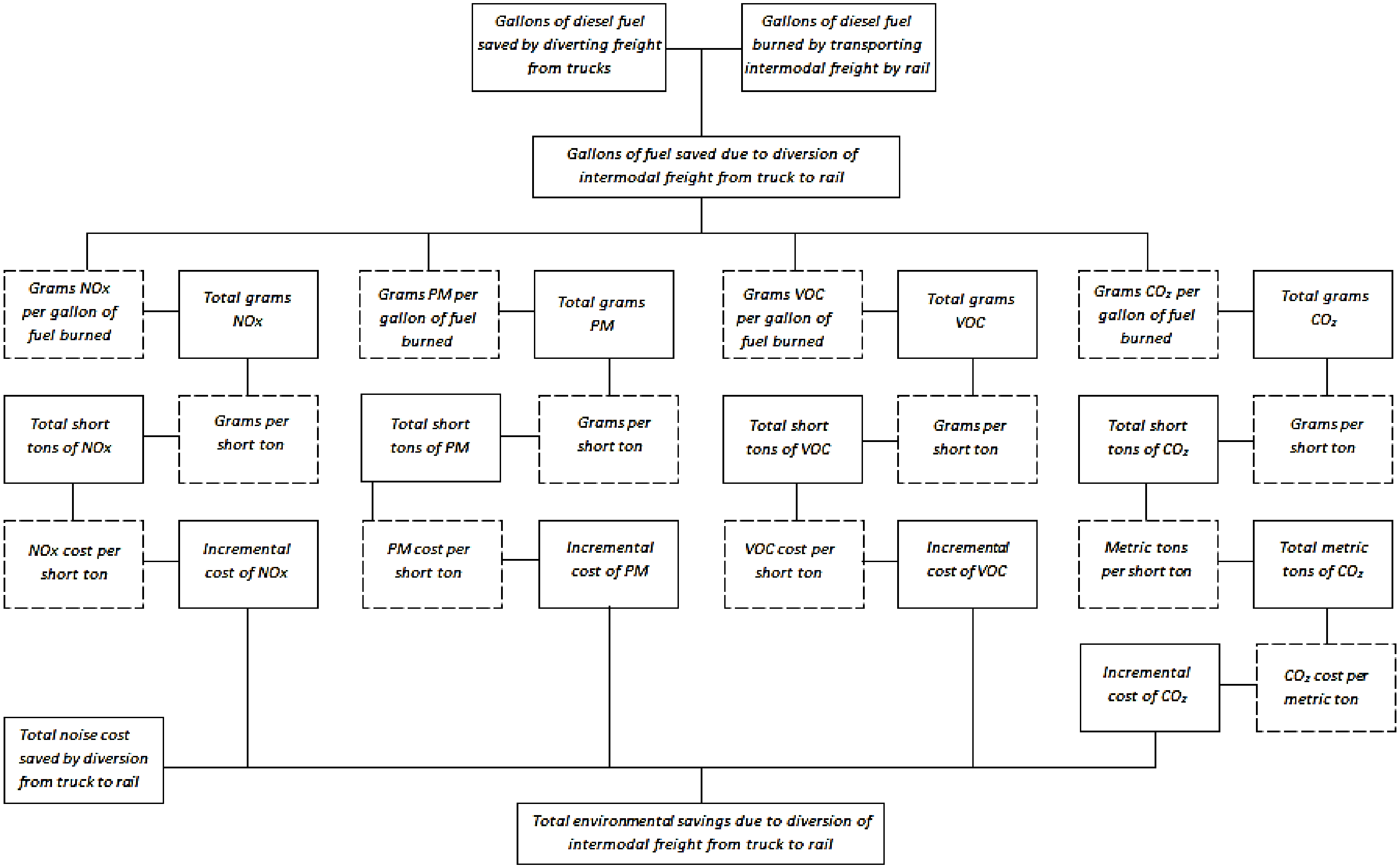
Transportation Cost Savings due to Diverting Intermodal Freight from Truck to Rail



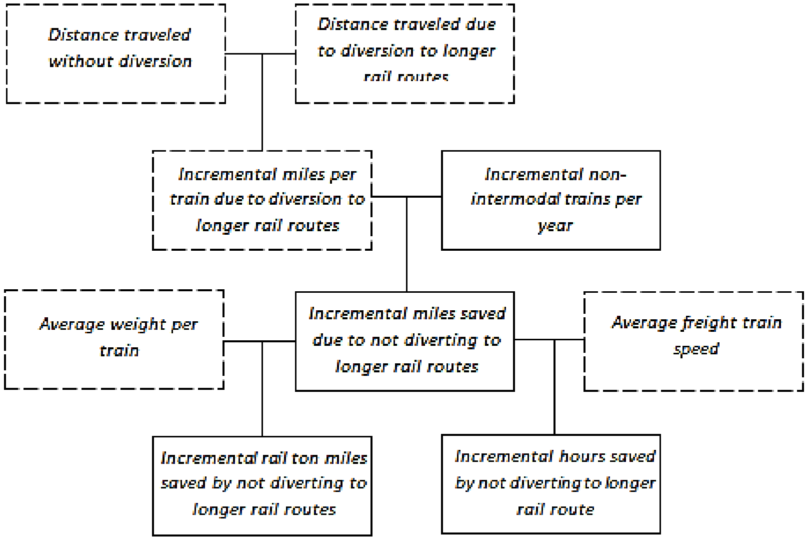
Transportation Savings due to Diverting Intermodal Freight from Truck to Rail



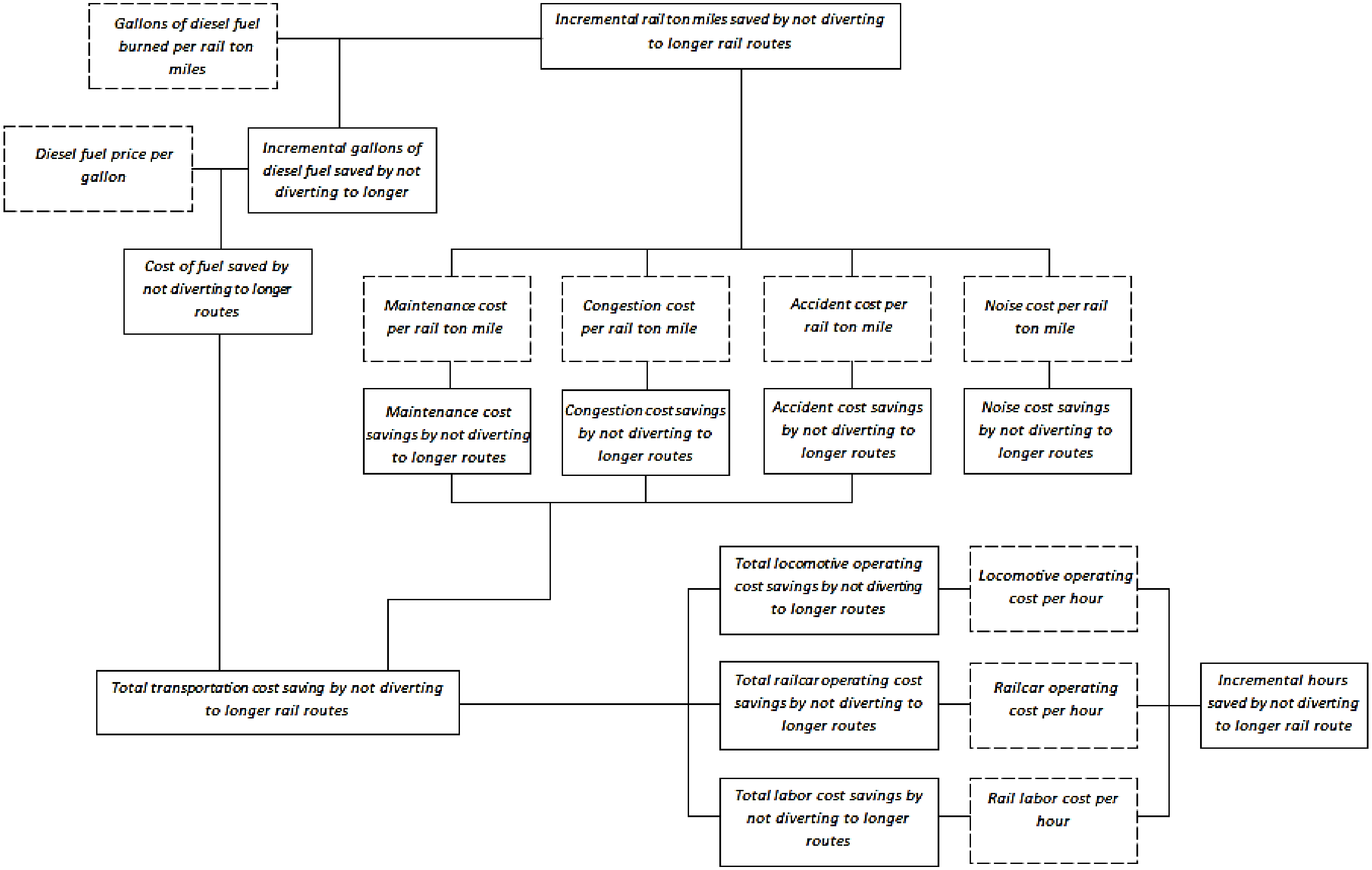
Environmental Cost Savings due to Diversion of Intermodal Freight from Truck to Rail



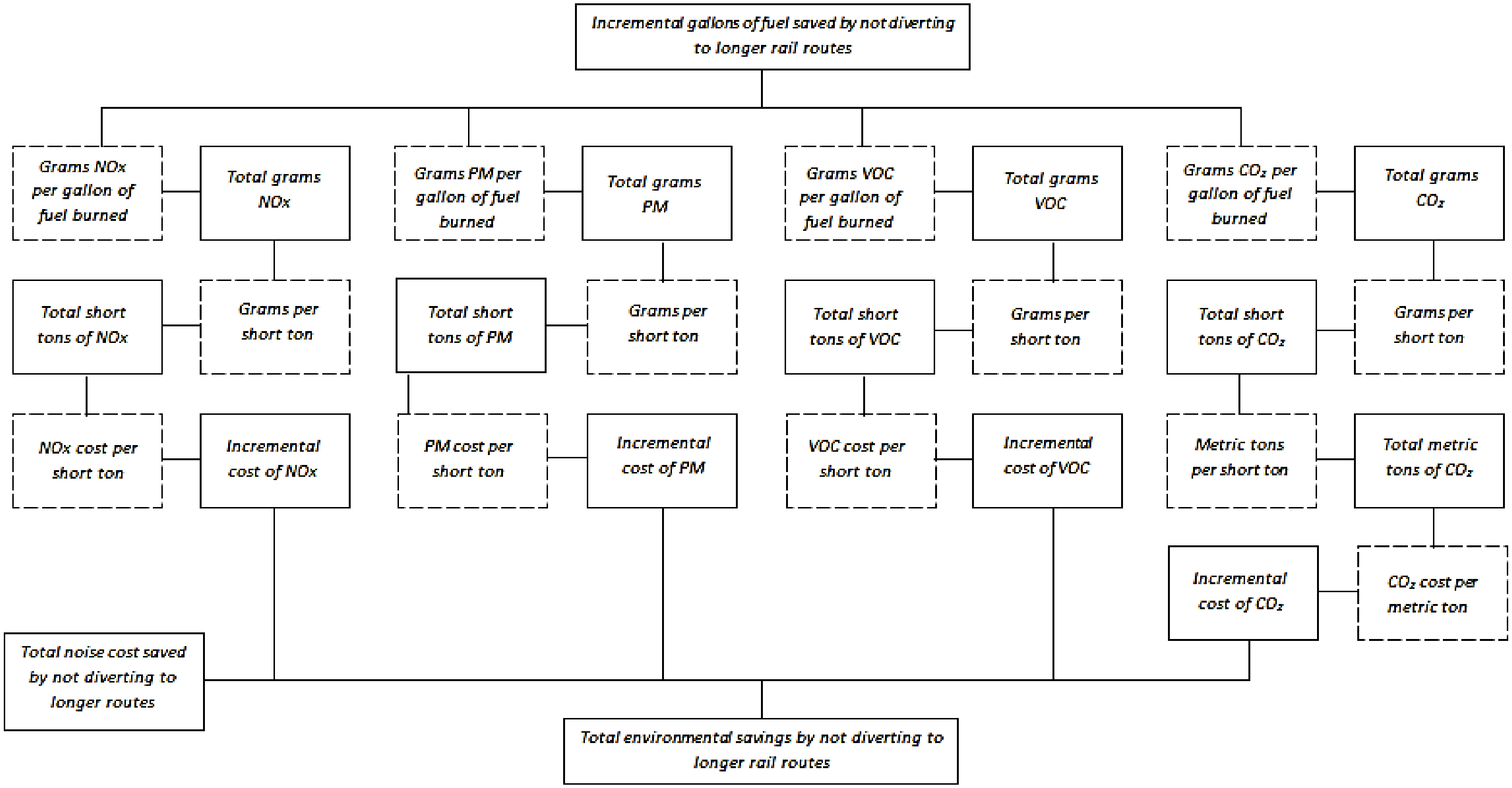
Incremental Miles Saved by not diverting to Longer Rail Routes



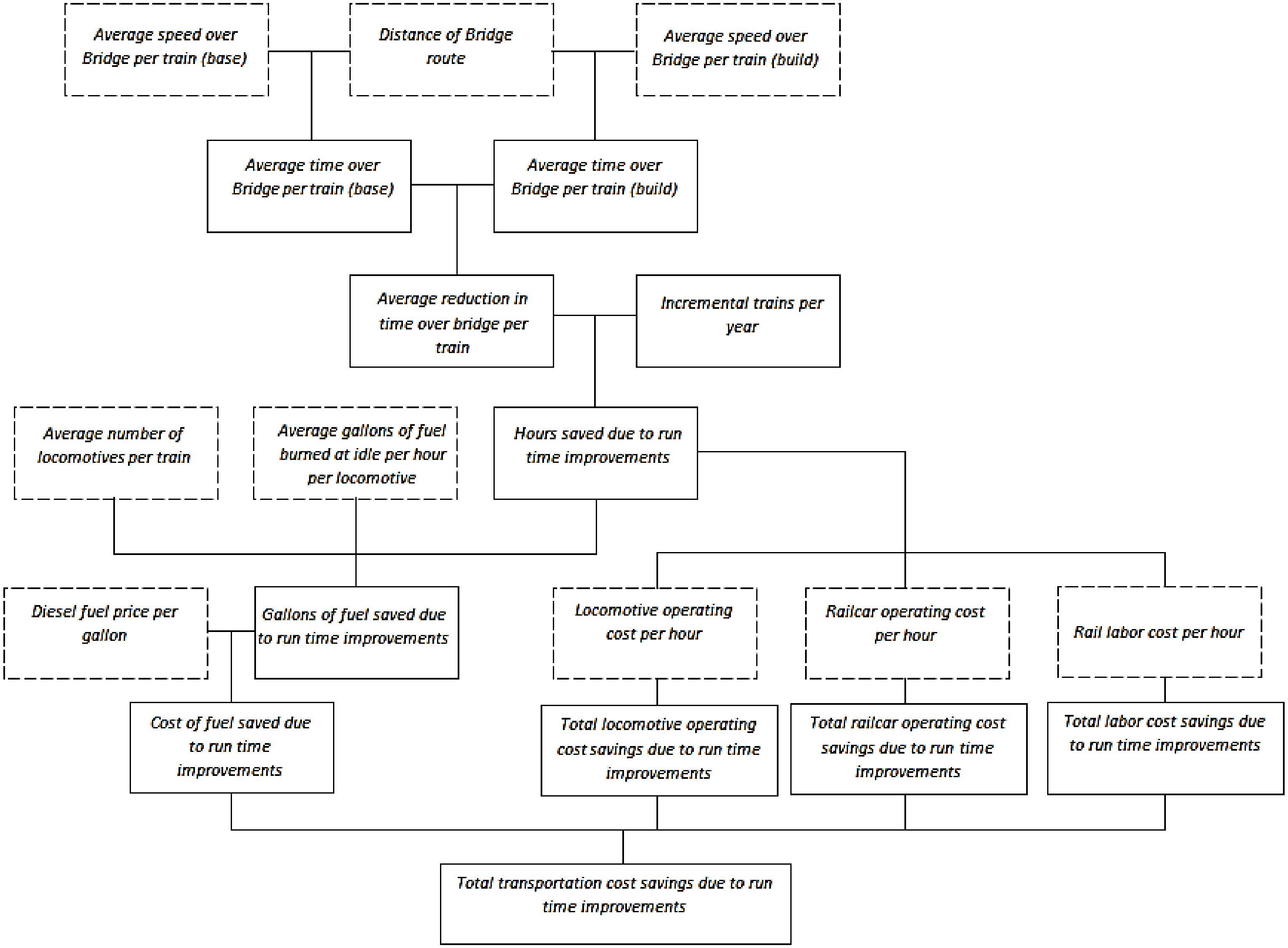
Transportation Cost Savings by not diverting to Longer Rail Routes



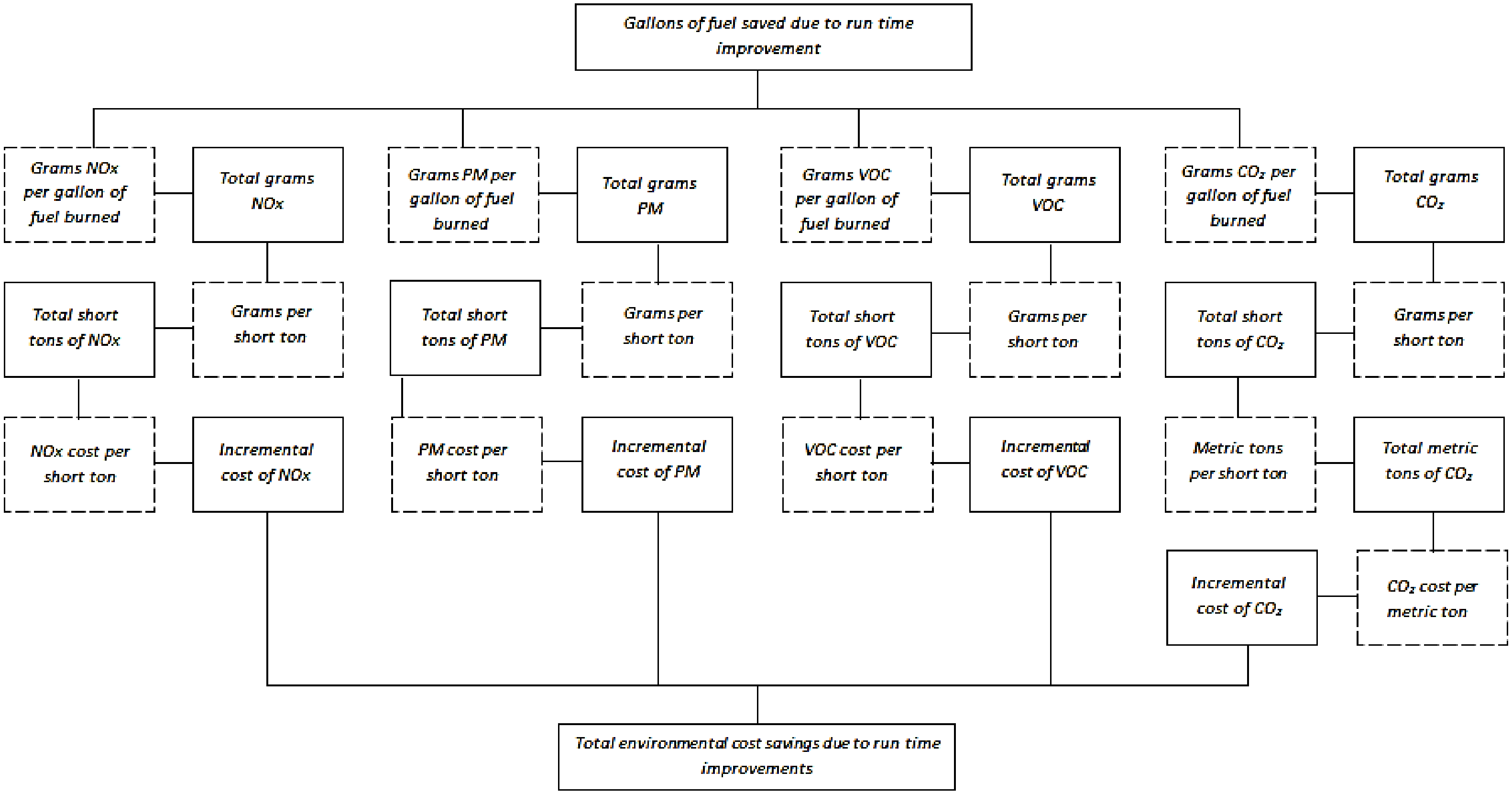
Environmental Cost Savings by not diverting to Longer Rail Routes



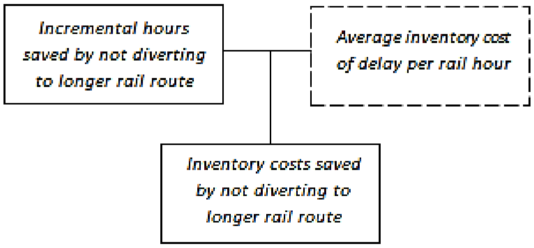
Transportation Cost Savings Due to Run Time Improvements



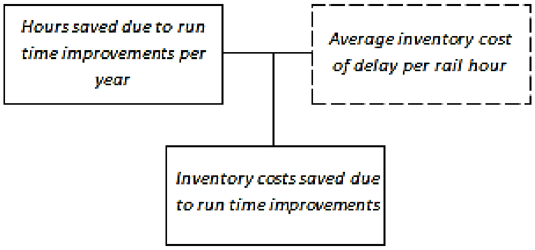
Environmental Cost Savings due to Run Time Improvements



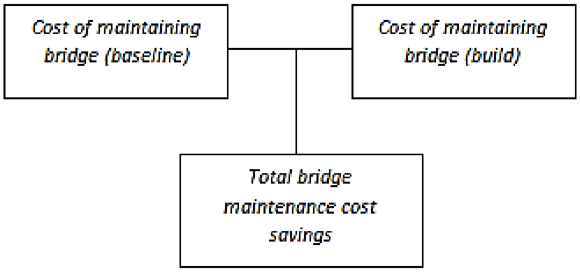
Inventory Cost Savings by not diverting to Longer Rail Routes



Inventory Cost Savings due to Run Time Improvements



Bridge Maintenance Cost Savings due to Project



APPENDIX C. COST-BENEFIT MODEL INPUTS AND SOURCES

Input	Unit	Value	Source
Average Trains per day (baseline)	#	32.3	TRRA – 2014 figure adjusted yearly for the annualized growth rate in total tonnage over the 20 year horizon
Average Trains per day (build)	#	80.8	Anticipated tonnage growth of 150% from project applied to TRRA 2014 baseline figure
Peak Volume Trains per day (baseline)	#	40	TRRA – 2014 figure
Bridge Closure due to maintenance (baseline)	days per year	12	TRRA
Bridge Closure due to maintenance (build)	days per year	6	TRRA
Trains per year after Maintenance (baseline)	trains per year	11401.9	TRRA – 2014 trains per day adjusted for annual bridge closure
Trains per year after Maintenance (build)	trains per year	28989.3	TRRA – Anticipated trains per day adjusted for estimated closure
Annualized growth rate in tonnage	%	0. 78	FRA, National Rail Plan Progress Report, September 2010: www.fra.dot.gov/eLib/Details/L02696 Derived from estimate of 35% increase in total tonnage by 2050
Total Growth in Trains After Project	%	150	TRRA – Derived from expected annual tonnage to increase from 40MGT to 100MGT after project
Percent of Intermodal Trains Using Bridge	%	0. 633	TRRA – 2014 figure
Average Tons Per Train	tons per train	3,488	AAR, Class I Railroad Statistics, July 15, 2014 report: www.aar.org/Documents/Railroad-Statistics.pdf
Distance travelled to use Merchants Bridge or MacArthur Bridge crossing	miles	7	TRRA
Distance Traveled to Use Diversion Route	miles	300	TRRA
Annual bridge maintenance cost (baseline)	$ per year	$200,000.00	TRRA
Annual bridge maintenance cost (build)	$ per year	$100,000.00	TRRA estimate
Average speed over bridge (baseline)	mph	6	TRRA
Average speed over bridge (build)	mph	14	TRRA estimate
Industry Average Freight Train Speed	mph	23.9	Bureau of Transportation Statistics, 2009: www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/transportation_statistics_annual_report/2010/html/chapter_02/table_04_33.html
Average length of trip by rail	miles	617	AASHTO, Freight-Rail Bottom Line Report, 2000, Figure 10: rail.transportation.org/Documents/FreightRailReport.pdf
Average Revenue per ton-Mile (rail)	$ per ton-Mile	$0.0455	AAR, Class I Railroad Statistics, July 15, 2014 report: www.aar.org/Documents/Railroad-Statistics.pdf 2013 figure put into 2015 dollars.
Revenue Ton Miles Per gallon of fuel consumed (rail)	Ton Miles per gallon	480	FRA Best Practices and Strategies for Improving Rail Energy Efficiency, January 2014: ntl.bts.gov/lib/51000/51000/51097/DOT-VNTSC-FRA-13-02.pdf

Input	Unit	Value	Source
Gallons of Fuel Burned per Revenue Ton-Mile, 2014	Gallon per Ton Mile	0.002083	Derived from Revenue Ton Miles per Gallon of Fuel FRA Best Practices and Strategies for Improving Rail Energy Efficiency, January 2014: ntl.bts.gov/lib/51000/51000/51097/DOT-VNTSC-FRA-13-02.pdf
Gallons of Fuel Burned per Revenue Ton-Mile, 2015	Gallon per Ton Mile	0.002063	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010 FRA Best Practices and Strategies for Improving Rail Energy Efficiency, January 2014: ntl.bts.gov/lib/51000/51000/51097/DOT-VNTSC-FRA-13-02.pdf
Average number of Locomotives per train	#	3	TRRA
Average Weight per Truck	tons	16	U.S. Department of Transportation, Freight Story 2008, 2008. ops.fhwa.dot.gov/freight/freight_analysis/freight_story/major.htm
Average Freight Truck Speed	Miles per hour	56.8	U.S. Department of Transportation. Federal Highway Administration. Freight Facts and Figures 2010, Table 3-8. Average Truck Speeds on Selected Interstate Highways: 2009. ops.fhwa.dot.gov/ freight/freight_analysis/nat_freight_stats/docs/10factsfigures/table3_ 8.htm (Used Value for Interstate 70)
Average fuel consumed per 1000 truck ton miles	Gallons per 1000 truck-ton miles	6.5	Oak Ridge National Laboratory. Vehicle Technologies Market Report. 2014. Chapter 3, Heavy Trucks. cta.ornl.gov/vtmarketreport/pdf/chapter3_heavy_trucks.pdf
Average Number of Containers per Intermodal Train	Containers per train	110.7	Cambridge Systematics Inc., National Rail Freight Infrastructure Capacity and Investment Study, AAR, September 2007. Using Eastern Railroad estimates: www.camsys.com/pubs/ AAR_Nat_%20Rail_Cap_Study.pdf
Average Number of Containers per Train (Non-Intermodal)	Containers per train	82	Cambridge Systematics Inc., National Rail Freight Infrastructure Capacity and Investment Study, AAR, September 2007. Using Eastern Railroad estimates: www.camsys.com/pubs/ AAR_Nat_%20Rail_Cap_Study.pdf
Number of containers per Truck	Containers per truck	1	1 container per truck
Average personnel cost per rail hour	$ per train-hour	$92.32	2014 TIGER Guidelines, put into 2015 dollars, based on TRRA estimate of 2 crew members per train.
Gallons of Fuel Burned per Revenue Ton-Mile, 2016	Gallon per Ton Mile	0.002042	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2017	Gallon per Ton Mile	0.002021	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2018	Gallon per Ton Mile	0.002001	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2019	Gallon per Ton Mile	0.001981	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2020	Gallon per Ton Mile	0.001961	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2021	Gallon per Ton Mile	0.001942	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2022	Gallon per Ton Mile	0.001922	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2023	Gallon per Ton Mile	0.001903	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010

Input	Unit	Value	Source
Gallons of Fuel Burned per Revenue Ton-Mile, 2024	Gallon per Ton Mile	0.001884	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2025	Gallon per Ton Mile	0.001865	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2026	Gallon per Ton Mile	0.001847	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2027	Gallon per Ton Mile	0.001828	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2028	Gallon per Ton Mile	0.001810	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2029	Gallon per Ton Mile	0.001729	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2030	Gallon per Ton Mile	0.001774	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2031	Gallon per Ton Mile	0.001756	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2032	Gallon per Ton Mile	0.001739	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2033	Gallon per Ton Mile	0.001721	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2034	Gallon per Ton Mile	0.001704	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2035	Gallon per Ton Mile	0.001687	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2036	Gallon per Ton Mile	0.001670	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
Gallons of Fuel Burned per Revenue Ton-Mile, 2037	Gallon per Ton Mile	0.001653	Applying an annual average of a 1% increase in efficiency as observed from 2000-2010
NOx cost per Ton	$ per short ton	$7,208.66	2014 TIGER Guidelines, put in 2015 dollars
PM cost per Ton	$ per short ton	$329,755.60	2014 TIGER Guidelines, put in 2015 dollars
VOC cost per ton	$ per short ton	$1,828.64	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2015	$ per metric ton	$42.36	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2016	$ per metric ton	$43.37	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2017	$ per metric ton	$44.38	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2018	$ per metric ton	$45.39	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2019	$ per metric ton	$46.40	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2020	$ per metric ton	$47.41	2014 TIGER Guidelines, put in 2015 dollars

Input	Unit	Value	Source
CO2 cost per ton, 2021	$ per metric ton	$48.41	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2022	$ per metric ton	$49.42	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2023	$ per metric ton	$50.43	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2024	$ per metric ton	$51.44	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2025	$ per metric ton	$53.46	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2026	$ per metric ton	$53.46	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2027	$ per metric ton	$55.47	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2028	$ per metric ton	$55.47	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2029	$ per metric ton	$56.48	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2030	$ per metric ton	$57.49	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2031	$ per metric ton	$58.50	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2032	$ per metric ton	$59.51	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2033	$ per metric ton	$60.52	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2034	$ per metric ton	$61.53	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2035	$ per metric ton	$62.53	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2036	$ per metric ton	$63.54	2014 TIGER Guidelines, put in 2015 dollars
CO2 cost per ton, 2037	$ per metric ton	$65.56	2014 TIGER Guidelines, put in 2015 dollars
NOx per gallon of fuel burned, 2015	grams per gallon	129	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2016	grams per gallon	121	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2017	grams per gallon	114	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2018	grams per gallon	108	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf

Input	Unit	Value	Source
NOx per gallon of fuel burned, 2019	grams per gallon	103	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2020	grams per gallon	99	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2021	grams per gallon	94	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2022	grams per gallon	89	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2023	grams per gallon	84	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2024	grams per gallon	79	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2025	grams per gallon	74	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2026	grams per gallon	69	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2027	grams per gallon	65	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2028	grams per gallon	61	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2029	grams per gallon	57	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2030	grams per gallon	53	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2031	grams per gallon	49	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2032	grams per gallon	46	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2033	grams per gallon	43	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2034	grams per gallon	40	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf

Input	Unit	Value	Source
NOx per gallon of fuel burned, 2035	grams per gallon	37	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2036	grams per gallon	35	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
NOx per gallon of fuel burned, 2037	grams per gallon	33	EPA, Emission Factors for Locomotives, April 2009, Table 5 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2015	grams per gallon	3.4	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2016	grams per gallon	3.1	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2017	grams per gallon	2.9	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2018	grams per gallon	2.7	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2019	grams per gallon	2.5	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2020	grams per gallon	2.3	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2021	grams per gallon	2.2	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2022	grams per gallon	2.0	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2023	grams per gallon	1.9	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2024	grams per gallon	1.7	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2025	grams per gallon	1.6	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2026	grams per gallon	1.5	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2027	grams per gallon	1.4	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf

Input	Unit	Value	Source
PM per gallon of fuel burned, 2028	grams per gallon	1.3	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2029	grams per gallon	1.1	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2030	grams per gallon	1.0	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2031	grams per gallon	1.0	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2032	grams per gallon	0.9	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2033	grams per gallon	0.8	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2034	grams per gallon	0.7	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2035	grams per gallon	0.7	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2036	grams per gallon	0.6	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
PM per gallon of fuel burned, 2037	grams per gallon	0.6	EPA, Emission Factors for Locomotives, April 2009, Table 6 – Large Line-Haul Locomotives: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2015	grams per gallon	5.7	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2016	grams per gallon	5.1	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2017	grams per gallon	4.6	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2018	grams per gallon	4.2	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2019	grams per gallon	3.9	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2020	grams per gallon	3.6	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf

Input	Unit	Value	Source
VOC per gallon of fuel burned, 2021	grams per gallon	3.4	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2022	grams per gallon	3.2	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2023	grams per gallon	3.0	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2024	grams per gallon	2.8	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2025	grams per gallon	2.6	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2026	grams per gallon	2.5	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2027	grams per gallon	2.3	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2028	grams per gallon	2.1	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2029	grams per gallon	2.0	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2030	grams per gallon	1.9	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2031	grams per gallon	1.7	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2032	grams per gallon	1.6	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2033	grams per gallon	1.5	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2034	grams per gallon	1.4	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2035	grams per gallon	1.3	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
VOC per gallon of fuel burned, 2036	grams per gallon	1.2	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf

Input	Unit	Value	Source
VOC per gallon of fuel burned, 2037	grams per gallon	1.2	EPA, Emission Factors for Locomotives, April 2009, Table 7 – Large Line-Haul Locomotives, assume HC equals VOC: www.epa.gov/nonroad/locomotv/420f09025.pdf
Pounds of CO2 per gallon of diesel fuel burned	pounds per gallon	22.38	U.S. Energy Information Administration, March 2015: www.eia.gov/tools/faqs/faq.cfm?id=307&t=11
Grams per Pound	grams per pound	453.592	Unit conversion factor
Grams of CO2 per gallon of diesel fuel burned	grams per gallon	10151.397	Calculated
Grams per Short Ton	grams per short ton	907,185	Unit conversion factor
Metric Ton per Short Ton	metric tons per short ton	0.907185	Unit conversion factor
Diesel Fuel Price, 2015	$ per gallon	$3.4349	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2016	$ per gallon	$3.4920	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2017	$ per gallon	$3.5654	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2018	$ per gallon	$3.6314	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2019	$ per gallon	$3.7014	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2020	$ per gallon	$3.7470	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a

Input	Unit	Value	Source
Diesel Fuel Price, 2021	$ per gallon	$3.8236	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2022	$ per gallon	$3.9114	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2023	$ per gallon	$3.9633	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2024	$ per gallon	$4.0187	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2025	$ per gallon	$4.0811	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2026	$ per gallon	$4.1333	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2027	$ per gallon	$4.1851	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2028	$ per gallon	$4.2389	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2029	$ per gallon	$4.2905	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a

Input	Unit	Value	Source
Diesel Fuel Price, 2030	$ per gallon	$4.3390	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2031	$ per gallon	$4.3853	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2032	$ per gallon	$4.4433	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2033	$ per gallon	$4.5140	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2034	$ per gallon	$4.5897	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2035	$ per gallon	$4.6749	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2036	$ per gallon	$4.7662	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Diesel Fuel Price, 2037	$ per gallon	$4.8507	EIA, Annual Energy Outlook 2014, Table 12 – Petroleum Product Prices, put into 2015 dollars: www.eia.gov/oiaf/aeo/ tablebrowser/#release=AEO 2014&subject=0-AEO2014&table=12-AEO2014&region=0-0&cases=full2013full-d102312a,ref2014-d102413a
Gallons of Fuel at Idle per Locomotive	gallons per hour per locomotive	5.25	ARRC, Alaska Railroad Corporation, Locomotive Overhauls and Emission Reduction, January 2011, derived from daily PM emissions at idle using SD-70 series locomotive: www.alaskarailroad.com/Portals/6/pdf/pr/2011_06_14_Appx_10_Loco_Emissions_PR.pdf
Pavement maintenance cost per truck ton mile	$ per truck ton-mile	$0.1878	FHA, Addendum to the 1997 Federal Highway Cost Allocation Study Final Report, May 2000. Put into 2015 dollars: www.fhwa.dot.gov/policy/hcas/addendum.htm

Input	Unit	Value	Source
railroad maintenance cost per rail ton-mile	$ per rail ton-mile	$0.000596	Congressional Budget Office, Social-Cost Pricing in Freight Transportation, December 2014: www.cbo.gov/sites/default/files/cbofiles/attachments/49838-Social_Cost%20_Pricing_Freight_Transportation.pdf
Congestion cost per truck ton-mile	$ per truck ton mile	$0.0518	FHA, Addendum to the 1997 Federal Highway Cost Allocation Study Final Report, May 2000. Put into 2015 dollars: www.fhwa.dot.gov/policy/hcas/addendum.htm
Congestion cost per train ton-mile	$ per rail ton-mile	$0.000296	Congressional Budget Office, Social-Cost Pricing in Freight Transportation, December 2014: www.cbo.gov/sites/default/files/cbofiles/attachments/49838-Social_Cost%20_Pricing_Freight_Transportation.pdf
Accident cost per truck ton mile	$ per truck ton mile	$0.0119	FHA, Addendum to the 1997 Federal Highway Cost Allocation Study Final Report, May 2000. Put into 2015 dollars: www.fhwa.dot.gov/policy/hcas/addendum.htm
Accident cost per freight train ton mile	$ per train ton-mile	$0.002485	Congressional Budget Office, Social-Cost Pricing in Freight Transportation, December 2014: www.cbo.gov/sites/default/files/cbofiles/attachments/49838-Social_Cost%20_Pricing_Freight_Transportation.pdf
Noise cost per truck ton mile	$ per truck ton-mile	$0.0061	FHA, Addendum to the 1997 Federal Highway Cost Allocation Study Final Report, May 2000. Put into 2015 dollars: www.fhwa.dot.gov/policy/hcas/addendum.htm
Noise cost per train ton mile	$ per train ton-mile	$0.000533	Forkenbrock, David J., Comparison of external costs of rail and truck freight transportation, University of Iowa, October 1999. Put into 2015 dollars: nexus.umn.edu/Courses/ce8214/papers/Forkenbrock2001.pdf
Average Lading Delay Cost	$ per train hour	$528.16	Lovett, Alexander H., C. Tyler Dick, Christopher P. L. Barkan. Determining Freight Train Delay Costs in Railroad Lines in North America. University of Illinois at Urbana-Champaign. 2014. Estimates put into 2015 dollars: railtec.illinois.edu/articles/Files/Conference%20Proceedings/2015/Lovett-et-al-2015-IAROR.pdf
Locomotive Operating Cost	$ per locomotive hour	$67.39	Lovett, Alexander H., C. Tyler Dick, Christopher P. L. Barkan. Determining Freight Train Delay Costs in Railroad Lines in North America. University of Illinois at Urbana-Champaign. 2014. Estimates put into 2015 dollars: railtec.illinois.edu/articles/Files/Conference%20Proceedings/2015/Lovett-et-al-2015-IAROR.pdf
Intermodal rail car cost per hour	$ per hour	$1.01	Lovett, Alexander H., C. Tyler Dick, Christopher P. L. Barkan. Determining Freight Train Delay Costs in Railroad Lines in North America. University of Illinois at Urbana-Champaign. 2014. Estimates put into 2015 dollars: railtec.illinois.edu/articles/Files/Conference%20Proceedings/2015/Lovett-et-al-2015-IAROR.pdf

Input	Unit	Value	Source
Manifest rail car cost per hour	$ per hour	$0.85	Lovett, Alexander H., C. Tyler Dick, Christopher P. L. Barkan. Determining Freight Train Delay Costs in Railroad Lines in North America. University of Illinois at Urbana-Champaign. 2014. Estimates put into 2015 dollars: railtec.illinois.edu/ articles/Files/Conference%20Proceedings/2015/Lovett-et-al-2015-IAROR.pdf