Chapter 26

Highway-Rail Grade Crossings

Introduction

The amount of freight transported by railroads is expected to double over the next twenty years. Train volumes at some grade crossings will more than double as railroads consolidate traffic on major corridors to improve efficiency and cut costs. Some crossings currently serve as many as 140 trains per day, and the number of crossings serving more than 100 trains per day will more than double in the next 20 years. Crossings near intermodal facilities, ports, major rail yards, and classification and switching areas will experience high train and truck traffic increases due to increases in domestic and foreign trade.

> **Q. What is a highway-rail grade crossing?**
>
> **A.** A highway-rail grade crossing is the intersection of highway lanes and railroad track. The Federal Railroad Administration has identified over 260,000 public and private grade crossings in the United States. Passive warning devices protect over 78 percent of the grade crossings. Flashing lights, automated gates, and other train activated warning devices protect the remaining grade crossings. State and local governments have the responsibility of enforcing traffic laws at highway-rail grade crossings.

One result of the increased rail traffic will be that more grade crossings will be closed to highway traffic for long periods of time each day. Coupled with expected increases in auto and truck traffic, highway delay is likely to increase significantly at highway-rail grade crossings. The delay to motorists and pedestrians could reach unacceptable levels in many communities, blocking emergency vehicles, disrupting local commerce, inconveniencing residents, and creating societal divisions.

> **Q. Does this analysis cover highway-rail grade crossing safety?**
>
> **A.** Traditionally, grade crossings have been viewed as a safety concern. This analysis focuses on delay-related highway user costs and includes safety. For more information on grade crossing safety, see Chapter 20.

The Federal Railroad Administration (FRA) has analyzed grade crossings located on the Federal-aid highway system characterized by high volumes of highway and rail traffic, each of which is currently protected by both flashing lights and gates. These crossings can be closed for large portions of the day, causing significant delay to both passenger vehicles and trucks.

The FRA analysis suggests that during the first ten years of the 20-year analysis period, total hours of delay for trucks, autos, and buses could increase by 7 percent per year. The annual increases could reach 15 percent annually in the last ten years of the analysis period, depending on whether trains travel through crossings when highway traffic volume is at its highest. Annual hours of delay for autos could increase to between 35 million and 123 million hours by 2022, and trucks could spend between 4.9 and 6.6 million more hours annually behind closed gates by 2022 than at the present, depending on how frequently trains arrived at the gates during daily highway traffic peaks. The cost to highway users in lost time at the most heavily traveled crossings on the Federal-aid system would increase to between $5.5 and $7.8 billion over the 20-year analysis period.

The solutions to this problem are either to separate the railroad and highway at the crossing, or to place restrictions on the frequency and duration of highway closures at grade crossings. While the former solution requires expensive construction, the latter restricts the capacity and flexibility of railroad operations, creates economic costs for the railroad and its shippers, and reduces the ability of railroads to serve as a substitute for truck traffic on increasingly crowded highways.

Grade Separation Improvements

When traffic volumes reach the levels noted above, the most effective solution may be to separate highway and rail traffic by building a bridge. The analysis of the costs and benefits of grade separation investment presented here focuses on the length of time highway vehicles spend queued up waiting for the train to pass. Most important is determining how many highway vehicles are affected each time a train arrives at the crossing. The analysis was done only for grade crossings on the Federal-aid highway system.

Q. What assumptions were made about highway and rail traffic to estimate the change in highway user costs resulting from these funding levels?

A. The highway user costs used in Figure 26-1 are the average of the two traffic scenarios, uniform and peak, established in this analysis. All highway user cost estimates depend on the amount of highway traffic affected when trains arrive at grade crossings.

Exhibit 26-1 shows the projected changes in different types of highway user and emissions costs in 2022 (compared to 2002 levels) at different annual levels of investment in grade separation improvements. The analysis indicates that:

- An average annual investment in highway-rail grade separation improvements of $300 million would be sufficient to maintain highway user costs at these crossings at the 2002 level. This investment level is comparable to the "Maintain User Costs" scenario for highways discussed in Chapter 7.

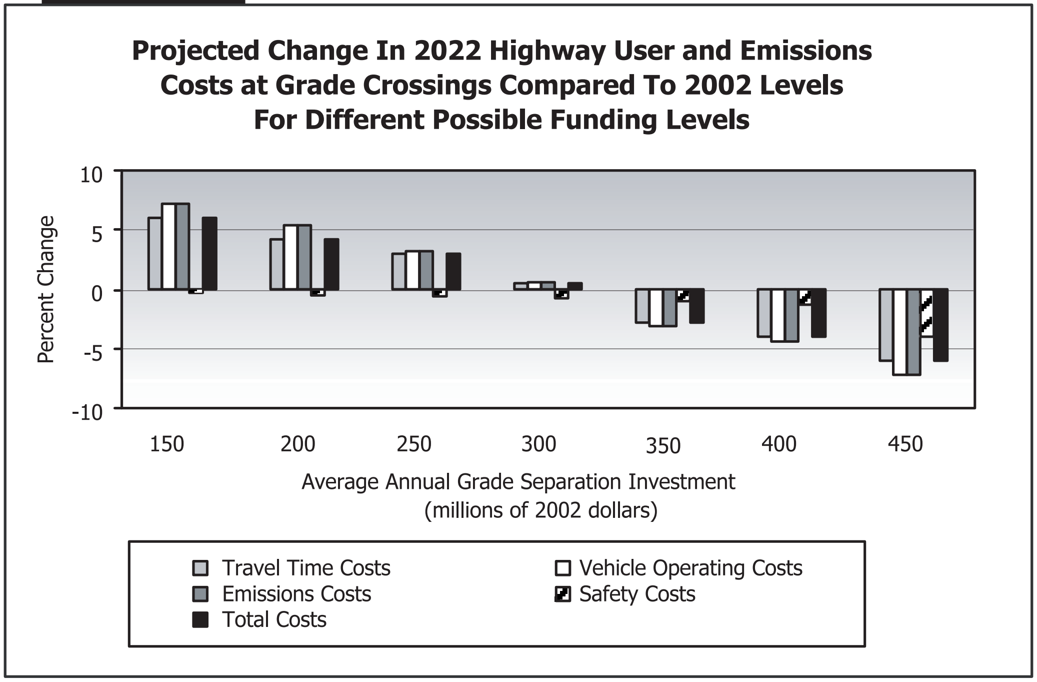
- Increasing average annual investment to $450 million would be sufficient to undertake all cost beneficial separation projects at grade crossings on the Federal aid system. This level is comparable to the "Maximum Economic Investment" scenario for highways discussed in Chapter 7.

- Grade separation improvements are at least partially captured in the external adjustments made in Chapter 7 to account for non-modeled capital investments. However, the grade separation projects analyzed by FRA may also include additional investments that are not fully reflected in the two highway investment scenarios.

As with the highway and bridge analyses presented in Chapter 7, the FRA analysis finds that there is a significant backlog of grade separation improvements that could be immediately justified. The backlog of such improvements in 2002 totals $2.0 billion.

In practice, grade crossing separations are planned in combination with the closing of adjacent grade crossings. Highway traffic is rerouted from the closed to the grade separated crossing. As a result, the grade separation eliminates wait time at the closed and the separated crossing. While a more thorough analysis would consider the benefits associated with the redirected traffic, they are not included in this analysis, nor is the residual value of capital investments in grade separation.

Exhibit 26-1



Grade Crossing Traffic Distribution Scenarios

Delays at grade crossings occur when highway and rail traffic meet at grade crossings. The analysis of such delay thus depends on assumptions about the distribution of highway and rail traffic among different time periods. In the FRA analysis, two traffic distribution scenarios were analyzed: peak traffic and uniform traffic.

> **Q. How were highway and railroad daily traffic volumes distributed over a 24-hour period?**
>
> **A.** Two scenarios, uniform and peak, were established to evaluate a reasonable range of highway traffic volumes affected by grade crossing closures. In the uniform scenario, parameters were set so that highway and rail traffic are evenly distributed across each hour of the day. The peak scenario sets parameters to adjust daily traffic volumes so that 48 percent of daily highway traffic is allowed to peak at an increasing rate over 6 hours of the day to a maximum peak of .08 percent of daily traffic. All highway traffic above 900 vehicles per lane per hour is redirected away from the crossing. The costs and benefits of redirecting traffic are not included in this analysis. Thirty-seven percent of daily traffic is distributed evenly over the next 12 hours and the remaining 15 percent is distributed evenly for remaining six hours. Train traffic is allowed to cluster at any time including the 6-hour peak period for highway traffic.

Peak Traffic

As shown in Exhibit 26-2, allowing both highway and train traffic to peak at grade crossings could result in auto delay increasing to 123 million hours annually by 2022. Similarly, trucks would likely experience an additional 6.6 million hours of delay annually in 20 years, and annual bus delay could increase to 6.0 million hours annually. The present value of delay for all vehicles for the 20year period is valued at $7.9 billion at the 50 percent confidence level. In other words, under these assumptions, one can be 50 percent certain that hours of delay would equal or exceed the values stated above. At the 50 percent confidence interval, annual carbon

Exhibit 26-2

Annual Increase in Delay and Associated Costs for Sample Crossings in 2022 Compared to 2003 Levels

CONFIDENCE INTERVAL		50%	80%	20%
Scenario: Peak		**Average**	**Minimum**	**Maximum**
Delay (hours)	Auto	123,217,150	66,518,097	174,509,523
	Truck	6,661,616	3,540,633	9,478,470
	Bus	5,994,450	3,233,261	8,503,662
Emissions (metric tons)	CO	519,186	75,452	198,485
	HC	32,488	19,508	44,131
	NOx	11,144	6,694	15,095
Fuel Consumption (gallons)	Gasoline	969,352,821	581,967,155	1,318,567,725
	Diesel	147,395,271	147,395,271	147,395,271
	Oil	72,063,230	72,063,230	72,063,230
		Present Value of All Costs for the Entire 2003-2022 Analysis Period		
Costs (000's)	Safety	$457,242	$453,813	$460,180
	Delay	$7,854,596	$4,156,804	$11,360,507
	Emissions	$43,968	$24,779	$61,021
	Vehicle Operating Costs	$669,946	$377,815	$929,103
	Total	$9,033,694	$5,021,964	$12,817,903

monoxide emissions would increase by 519,186 metric tons, annual hydrocarbon emissions would increase by 32,488 metric tons, and annual nitrogen oxide emissions would increase by 11,144 metric tons. Total emissions for the 20-year analysis period add up to a present value of nearly $44 million. Again, at the 50 percent confidence interval, annual fuel burned idling at grade crossings increases by 969 million gallons of gasoline, 147 million gallons of diesel, and 72 million gallons of oil. Vehicle operating costs are the sum of additional fuel and oil burned while idling at grade crossings and add a present value of $669 million to total costs. All categories of accidents combined add an additional $457,242 in present value costs to the total.

Q. **How was this analysis conducted?**

A. FRA relied on its *GradeDec 2000* software to conduct a Monte Carlo simulation to provide a range of values for all benefit categories at the 20, 50, and 80 percent confidence intervals for each scenario. Train length is allowed to vary from 30 to 90 cars, and the number of passenger rail trains varies between zero and four. All other variables were held constant.

On average, the total increase in costs for all years and all categories over the 20-year analysis period is valued at more than $9 billion in present-value dollars. Thirty-five percent of the deviation from the mean is attributed to variations in train length and 15 percent is attributed to the addition of passenger rail.

Uniform Traffic

Exhibit 26-3 shows that when highway and rail traffic is uniformly distributed, it is estimated that automobile traffic delay would increase over 35 million hours by the last year of the analysis period, trucks would spend 4.9 million hours delayed at crossings, and buses would be behind closed gates for 1.7 million hours more than in the base year (at the 50 percent confidence interval). The total value of time lost for all years in the analysis period amounts to a present value of $5.5 billion. Idling vehicles would emit 15,690 more metric tons of carbon monoxide annually, 988 more tons of hydrocarbons annually, and 359 more metric tons of nitrogen oxides annually than in 2002, the base year of the analysis. The changes in emissions over the analysis period convert to over $13 million present-value dollars. An additional 28.6 million gallons of gasoline, 6.5 million gallons of diesel, and 2.3 million gallons of oil would be burned at closed grade crossings than in the first year of the analysis period and would total $208 million in present-value dollars. Safety costs for all predicted categories: fatalities, injury, and property damage would be valued at $457,243. The total present-value costs of increased delay and safety at high volume grade crossings currently protected by flashing lights and gates on the Federal aid highway system would exceed $6.2 billion if all traffic is distributed evenly, which is an unlikely assumption.

In the uniformly distributed traffic scenario, 40 percent of the deviation from the mean is attributed to variation in the train length and 8 percent is attributed to the addition of passenger rail. This is expected because all traffic is uniformly distributed under this scenario, and thus the additional passenger trains would not be adding to congested conditions during peak traffic periods.

Exhibit 26-3

Annual Increase in Delay and Associated Costs for Sample Crossings in 2022 Compared to 2003 Levels

CONFIDENCE INTERVAL		**50%**	**80%**	**20%**
Scenario:Uniform		**Average**	**Minimum**	**Maximum**
Delay (hours)	Auto	35,442,034	18,885,489	50,791,114
	Truck	4,948,603	2,271,593	6,033,102
	Bus	1,653,771	881,544	2,367,674
Emissions (metric tons)	CO	15,690	8,265	22,525
	HC	988	520	1,418
	NOx	359	189	514
Fuel Consumption (gallons)	Gasoline	28,643,571	6,823,951	18,492,831
	Diesel	6,531,424	3,473,915	9,285,326
	Oil	2,272,354	1,198,495	3,258,217
	Present Value of All Costs for the Entire 2003-2022 Analysis Period			
Costs (000's)	Safety	$457,243	$453,813	$460,180
	Delay	$5,534,695	$2,924,706	$8,033,722
	Emissions	$13,788	$7,279	$20,012
	Vehicle Operating Costs	$207,752	$109,672	$301,459
	Total	**$6,218,933**	**$3,502,881**	**$8,818,933**

This analysis examines the warrants for grade separations related to highway traffic. Other promising research areas that may be addressed in the future include other warrants for grade separation, such as community cohesion.

Delay and Time in Queue at Individual Grade Crossings

The potential for rapid increases in grade crossing-related highway delay is easier to understand if one looks at what happens at an individual grade crossing as highway and train traffic increases.

Highway delay at grade crossings increases more than proportionally as highway and train traffic increase. As shown in the Exhibit 26-4, at lower highway traffic volumes, total delay for all vehicles is little more than 10 minutes if a grade crossing gate is closed for 3.6 minutes when there are 100 vehicles per lane per hour. In this case, 7 vehicles are affected, or lined up in the queue behind closed gates. But as highway traffic volumes increase, the number of affected vehicles increases from 7 to 110, so that at 900 vehicles per lane per hour, a total of 3.3 hours of delay would be experienced by all vehicles stopped behind the gates and total time in queue would equal 4 hours.

Q. **What is the difference between delay and time-in-queue?**

A. Delay is the amount of travel time lost while the grade crossings is closed. Time-in-queue differs from delay because it captures the amount of time it takes for vehicles to return to normal traffic flow. Delay is used to calculate changes in travel time, and time in queue is used to calculate vehicle operating costs and tons of emissions.

As train traffic volumes increase to near rail capacity, the average length of a train will also increase. Exhibit 26-5 shows that if the length of time a grade crossing is closed increases from 3.6 to 4.5 minutes, as would happen if a 60-car train added 20 additional cars, total hours of delay per train increases from 3.3 to 5 vehicle hours of delay, and time in queue would increase from 4 to 6 hours. The number of affected vehicles would increase from 110 for the 3.6-minute closure to 135 for the 4.5-minute closure at the 900 vehicles per lane per hour level.

As shown in Exhibits 26-4 and 26-5, as highway volumes and train lengths increase, so does the potential for significant increases in delay and time in queue. Also, at higher traffic volumes, the difference between delay and time-in-queue increases because it takes increasingly longer for the queue to disperse when the gates are opened. At these traffic volumes, the increases in highway user vehicle operating costs, or fuel and oil burned and resulting tons of emissions, outstrip travel time costs as the primary highway user cost associated with high volume highway rail grade crossings.

Exhibit 26-4

Delay and Time in Queue Per Lane for All Vehicles per 3.6 Minute Grade Crossing Closure

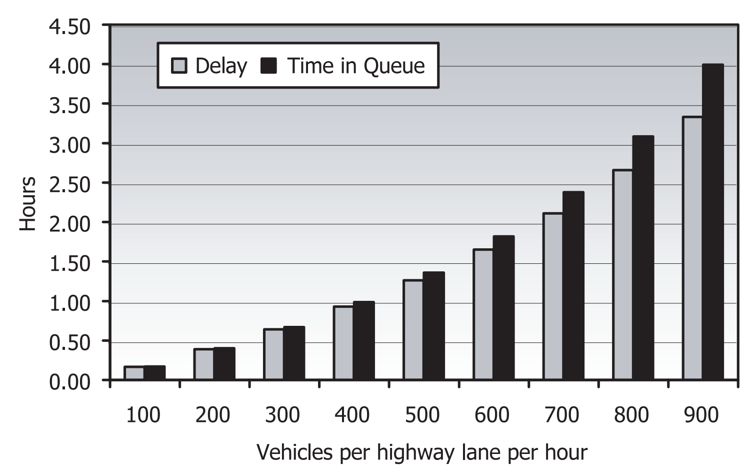
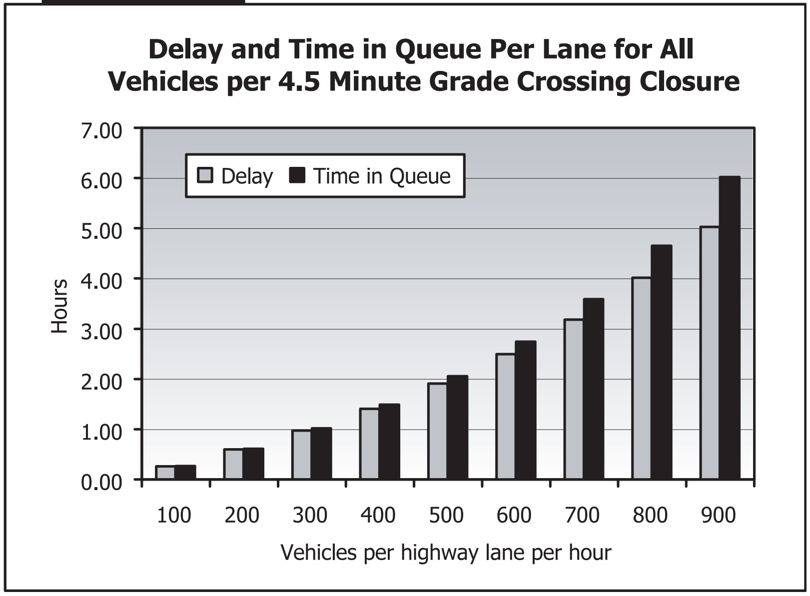


Exhibit 26-5


Delay and Time in Queue Per Lane for All Vehicles per 4.5 Minute Grade Crossing Closure
Delay
Time in Queue
Hours
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
100
200
300
400
500
600
700
800
900
Vehicles per highway lane per hour