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Development of a Methodology for Assessment of Crash Costs at Highway- Rail Grade Crossings in Nebraska

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16. Abstract

An accurate measure of crash costs is required to support effective decision-making about transportation investments. In particular, underinvestment will occur if measurement fails to capture the full cost of crashes. Such mis-measurement and underinvestment may be occurring in the case of crashes at highway-rail grade crossings (HRGCs). HRGC crash costs can be substantial because of the severity of crashes. However, another important potential cost is the disruption to the transportation and logistics system. Existing methodologies capture the first set of costs but often fail to fully capture the second set. This research provides a standardized methodology for assessing the expected annual crash costs at HRGCs in Nebraska, and the potential benefits from removing and replacing HRGC sites, for example, with an overhead bridge. Avoided crash costs are the primary benefit of safety improvements but logistics costs savings also are identified. Throughout the report, we trace a scenario using traffic conditions at the mean at-grade highway-rail crossing crash. We find that the cost of a crash, if it did occur, would be $805,675. The lifetime benefit of removing an at-grade intersection and replacing it with an overhead bridge or an underpass would be $235,836 given the traffic conditions at the mean Nebraska HRGC crash site. Given the relatively low traffic volumes found in many parts of Nebraska, at the mean crash site the injuries and deaths associated with crashes are the primary cost, with logistics costs accounting for a small share of costs (though exceeding the share of operating costs for trucks and rail). Naturally, benefits would vary given different traffic condition, with benefits rising if the number of motor vehicles and trains using a highway-rail at grade crossing increases. More generally, in this project we developed a spreadsheet which can be used to calculate the economic costs of individual crashes based on the AADT and detour time on the impacted roadway and train traffic and length of delay on the railway. This spreadsheet is available for simulation purposes and can be paired with information on the likelihood of crashes to determine the benefits of improving the safety of at-grade rail-highway intersections.

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Executive Summary

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This research provides a standardized methodology for assessing the expected annual crash costs at HRGCs in Nebraska, and the potential benefits from removing and replacing HRGC sites, for example, with an overhead bridge. Avoided crash costs are the primary benefit of safety improvements but logistics costs savings also are identified. Throughout the report, we trace a scenario using traffic conditions at the mean at-grade highway-rail crossing crash. We find that the cost of a crash, if it did occur, would be $805,675. The lifetime benefit of removing an at-grade intersection and replacing it with an overhead bridge or an underpass would be $235,836 given the traffic conditions at the mean Nebraska HRGC crash site. Given the relatively low traffic volumes found in many parts of Nebraska, the injuries and deaths associated with crashes are the primary cost at the mean crash site, with logistics costs accounting for a small share of costs (though exceeding the share of operating costs for trucks and rail). Naturally, benefits would vary given different traffic conditions, with benefits rising if the number of motor vehicles and trains using a highway-rail at grade crossing increases. More generally, in this project we developed a spreadsheet which can be used to calculate the economic costs of individual crashes based on the annual average daily traffic (AADT) and

detour time on the impacted roadway and train traffic and length of delay on the railway. This spreadsheet is available for simulation purposes and can be paired with information on the likelihood of crashes to determine the benefits of improving the safety of at-grade rail-highway intersections.

Chapter 1 Introduction

This research project develops a standardized methodology for assessing full crash costs at highway-rail grade crossings (HRGCs). Current methods for assessing the cost of highway crashes (Miller et al. 1991) consider the time costs of delays for vehicle operators, including freight operators, but do not consider the full economic costs on the logistics system. These costs can be substantial (Sedor and Caldwell 2002). For example, travel delays caused by congestion can impose costs on industries of up to $200 an hour for some time-sensitive products resulting from the need for transportation companies to add capacity and for shippers to add inventory (White and Grenzeback 2007). The cost of unexpected delays, such as accidents, can impose an additional 50% to 250% to the industry-wide cost of delays (HLB Decision Economics, Inc. 2001). And even these figures do not consider even larger costs associated with long truck and rail delays or detours that occur in the case of HRGC crashes, particularly those involving hazardous materials.

Thus it can be said that existing methodologies fail to capture the full costs for transportation carriers and the wider economy due to delays and re-routing, particularly for time sensitive or environmentally sensitive truck and rail cargo. This research develops a methodology that can be used to assess costs associated with crashes at HRGCs in Nebraska. The approach is based on fusing pertinent economic values with Nebraska data on traffic conditions at HRGC sites.

The research is based on a set of six research tasks, which are listed below. The results of each task are reported in Chapters 2 through 7 of this report. Chapter 8 provides a summary of findings.

Task 1: Literature Review

Task 2: Database construction

Task 3: Identification of truck economic factors

Task 4: Identification of rail economic factors

Task 5: Identification of driving public economic factors

Task 6: Development of methodology for HRGC crash cost estimation

Chapter 2 Literature Review

An extensive literature deals with the cost of vehicle crashes, including monetary costs for victims, time costs for victims, public safety system costs, delay costs for other vehicles, and pain and suffering of crash victims. These costs are typically measured for crashes of varying severity, as defined by the most severe injury experienced by victims in motor vehicle crashes. By contrast, there is relatively little information on the cost of crashes in terms of delays for the logistics system, or the additional costs from spills of hazardous materials. These are important omissions in the case of crashes at HRGCs. The unexpected nature of delays is critical for the logistics system, particularly in the context of lean manufacturing and just-in-time inventory systems. Traffic congestion, serious crashes, and other factors that delay supply deliveries cause firms to face the costs of carrying additional inventory, and cause transportation firms to face the contractual consequences of late deliveries. Crashes involving hazardous materials are especially likely to lead to long transportation delays. These crashes also involve a variety of additional potential costs, including the costs to residents and businesses from evacuations, and in some cases the cost of environmental remediation.

2.1 Detailed Findings

Existing methods for assessing the cost of highway crashes (Council et al. 2005; Blincoe et al. 2002; Blincoe 1996; and Miller et al. 1991) consider a wide array of costs. These include property damage, emergency service and medical costs, as well as future costs due to lost productivity and lost quality of life. The cost of congestion resulting from crashes is a component of lost productivity.[1] This literature is utilized in a variety of applied studies examining accident costs as well as other road user benefits that are influenced by transportation investments. For

[1] However, these costs refer to the time of drivers rather than systemic costs to the logistic system (which create the need for firms to carry additional inventory).

example, Thompson conducted benefit cost analysis of major transportation projects including the proposed Interstate 66 (Thompson et al. 1997) and Interstate 74 routes (Thompson et al. 2001). Thompson also developed a methodological handbook for conducting benefit cost analysis of transportation projects (Hall, Thompson, and Rosenbaum 2008), a software model for evaluating the benefits and costs of safety enhancements (Thompson 2003), and software for valuing the environmental impacts of highway investments for inclusion in benefit cost comparisons (Thompson 2004).

Crash cost estimates described above were developed for automobile and truck accidents, but similar methodologies are employed during benefit-cost analysis of rail safety projects, and for safety systems at highway-rail at-grade intersections. The Railroad-Highway Grade Crossing Handbook (Ogden 2007) recommends using cost data on injury accidents compiled by the National Highway Traffic Safety Administration when assessing safety improvements to at-grade intersections. This approach essentially calculates costs based on the number and severity of injuries (or number of deaths) in incidents at railroad-highway at grade crossings (Federal Highway Administration 2009), and the average economic cost of injuries or fatalities calculated in a highway setting. Such an approach is valuable but does not account for other differences (besides differences in injury and fatality rates) in the cost of rail versus motor vehicle accidents, including differences in vehicle damage severity, differences in traffic delays, and differences in the cost of damage to rail vehicles or equipment. Current approaches also do not reflect larger costs to the logistics system beyond the time costs of vehicle delays. As noted in the introduction, these costs can be substantial (Sedor and Caldwell 2002; White and Grenzeback 2007; HLB Decision Economics, Inc. 2001).

Another important issue in the rail industry is incidents involving hazardous materials hauled by train. Data from the Federal Railroad Administration (FRA 2009) indicates that there are typically between 25 and 40 incidents every year involving the release of hazardous materials and the evacuation of between 2,000 and 8,000 persons. These data suggest substantial costs for responding to Hazmat incidents, evacuations, and required environmental remediation, besides potential health and psychic costs to evacuees.

In summary, existing methodologies fail to capture the full costs of crashes at HRGCs. Current approaches do not account for the direct public safety and damage costs associated with rail-involved crashes, contingency costs for the logistic system due to crash occurrence, and costs associated with crashes involving hazardous materials. The latter issue is particularly important given the critical role that the rail industry plays in transporting hazardous materials.

Chapter 3 Database Construction

A comprehensive database of all public at-grade rail-highway crossing was developed in a geographic information system (GIS). The inventory includes crossings on major highways and streets in Nebraska, including those designated for transportation of hazardous materials. Key characteristics of the crossings are also added, such as the type of safety equipment present, estimates of the AADT and the split between cars and trucks, and the number of trains that pass through the crossing each day. The constructed database is housed and backed up at the Transportation Safety Research Laboratory in Whittier Building on the UNL city campus.

Using this approach, a database with 5,566 Nebraska crossings was developed. The database identified examples of at-grade crossings with both thousands of cars and trucks and more than one hundred trains passing each day. Obviously, the number of such crossings is limited given that such crossings in the past have received investments in overhead bridges or underpasses that replaced the at-grade crossing. Relatively few remain as a result. The average crossing has an AADT of 770, with trucks accounting for 4.4% of that traffic. An average of 14 trains per day passed through the 5,566 at-grade crossings in the database.

Chapter 4 Identification of Truck Economic Factors

This task involved identifying economic factors that are common to trucks involved in HRGC crashes. The research team held an extensive discussion with Mr. Larry Johnson, President of the Nebraska Trucking Association, regarding costs associated with HRGC crashes. The team also conducted a literature review considering the costs of trucking delays due to crashes and congestion. These costs can be substantial (Sedor and Caldwell 2002). For example, travel delays caused by congestion can impose costs on industries of up to $200 an hour for some time-sensitive products resulting from the need for transportation companies to add capacity and for shippers to add inventory (White and Grenzeback 2007). The logistic cost of unexpected delays, such as accidents, can impose an additional 50% to 250% to the industry-wide cost of delays (HLB Decision Economics, Inc. 2001). And these figures do not consider even larger costs associated with long truck and rail delays or detours that occur in the case of HRGC accidents, particularly crashes that could involve hazardous materials of sufficient toxicity to trigger road closures and evacuations.

Overall industry interviews and our review of the literature suggest that the relevant economic factors with HRGC accidents for trucks include the operating and time costs caused by road closures, as well as additional operating costs. In the case of trucks, these operating and time costs (including logistics costs) would primarily be costs associated with detouring in response to HRGC-induced road closures (with the exception of a truck involved in the HRGC accident). Trucks would be limited in detouring since many local roads may be ill-suited for carrying truck traffic. However, even if some trucks would need to be detoured to different towns, we anticipate that the average detour in Nebraska would be approximately 15 minutes.

The additional operating costs associated with detouring would be low relative to the much larger time costs of queuing at the closed highway.

As a result, our analysis focuses on the operating and time costs associated with detouring. Operating costs include the per-minute costs of operating a vehicle, including gasoline, maintenance, insurance costs, and vehicle depreciation, among other factors. The time costs associated with detouring primarily refer to value of driver time. We also consider crash costs, but these are primarily the costs for trucks that were involved in the HRGC. Finally, as noted earlier, we also consider the logistics costs associated with detouring.

We begin by calculating the per-minute costs of the additional ownership and operating expenditures, crash costs, and drive time associated with detours. In our model, these estimates would be multiplied by the number of trucks delayed (based on typical truck AADT on the closed HRGC) and the length of the detour in minutes in order to estimate truck costs associated with a particular HRGC crash.

The basic principles of these costs are described in Miller et al. (1991) and Hall, Thompson, and Rosenbaum (2008), and utilized in Thompson et al. (1997), Thompson et al. (2001), and Thompson (2003). Operating costs refer to all of the marginal costs associated with additional travel, such as fuel costs and the portion of ownership costs (maintenance, insurance, license, and depreciation) associated with truck usage, as opposed to the passing of time.

Table 4.1 illustrates calculations of depreciation costs following Hu (2008) and Waters et al. (1995). Calculations are based on a 5-axel diesel truck with trailer, the most common type of vehicle on the road. Those authors provided an average age for trucks of 2.5 years and an average depreciation rate of 16% per year. The combined new purchase cost of a truck and trailer was $128,554 in 1993 dollars, which was updated to a 2011 value of $192,111 based on the relevant producer price index.[2] The average annualized depreciation costs were calculated in Table 4.1. Note that the amount of depreciation listed in row 3 is for half a year. The average value of deprecation is $29,961 per year.

Table 4.1 Annual Depreciation Costs

Age of Truck	Beginning Value of Truck and Trailer	Depreciation Rate	Depreciation
0 year	$192,111	16%	$30,738
1 year	$161,373	16%	$25,820
2 year (1/2 year)	$133,554	8%	$10,844
Average Annual			$29,961

Hu (2008) and Waters et al. (1995) also provided information on the share of each cost factor that relates to vehicle usage rather than the passage of time. As seen in Table 4.2, 40% of annual depreciation costs are due to vehicle usage, compared to 20% for maintenance costs and 15% for insurance costs. These shares are used to calculate the average annual costs for each category and these costs are then divided by an average annual use of 3,000 hours to calculate hourly costs, except fuel, of $16.56. The hourly fuel costs of $32.17 were calculated based on $0.64 per mile ($3.86 per gallon of diesel and 6 miles per gallon) multiplied by an average travel of 50 miles in an hour.

These costs do not include the cost of driver time. The cost of driver time is the hourly wage plus the hourly value of benefits, as recommended by the Federal Highway Administration

[2] The increase in Trucks, over 14,000 lbs (WPU141106) over the 1993 to 2001 period was 49.4% = 100%*(200.1/133.9-1).

(FHWA) and utilized by Thompson et al. (2001). We assume one driver per truck so that the value of driver time per hour is the hourly wage and the benefits. Data from the U.S. Bureau of Labor Statistics indicate that the average hourly wage of long-haul truck drivers in Nebraska was $18.77 in May 2011. As for benefits, the Employer Health Benefits 2011 Annual Survey of the Kaiser Family Foundation indicates that the average value of health insurance benefits for family and single coverage was $7,794 in 2011. The 2007 Nebraska Employer Benefits Survey of the Nebraska Department of Labor indicated that 65% of full-time workers in the transportation sector receive health care benefits, so that health benefits are worth $5,066 per worker (including workers who do not receive benefits). That same survey also indicated that the value of retirement benefits were roughly 50% of health care benefits, suggesting an overall benefit level of $7,600 per truck driver per year. Dividing this by 2,000 hours per year yields an hourly benefit level of $3.80. The total hourly value of wages and benefits is $22.57, as seen in table 4.2.

The total cost per hour including fuel and driver time is $67.99 or $1.13 per minute of time spent traveling in detour. Total cost per mile of use also is calculated based on 50 miles per hour of travel. Total cost per mile is $1.36.

Table 4.2 Costs Due to Vehicle Use

Category	Annual Cost	Share Due to Use	Annual Cost Due to Use
Depreciation	$29,961	40%	$10,784
Opportunity Cost on Purchase (12% on purchase price)	$23,533	100%	$23,533
Maintenance	$15,170	20%	$3,034
Insurance	$6,523	15%	$978
License	$1,425	100%	$1,425
Total			$39,757
Hours Driven per Year			3,000
Cost per Hour of Use (excluding fuel and driver time)			$13.25
Fuel Cost per Hour			$32.17
Driver Time Cost per Hour			$22.57
Total Cost per Hour of Use			$67.99
Total Cost per Minute of Use			$1.133
Total Cost Per Mile of Use			$1.360

Source: Annual Costs from Hu (2008) and Waters et al. (1995).

As noted above, we assume an average detour of 15 minutes for trucks. Based on a 15 minute detour, the average operating cost for detoured vehicles would be $17.00.

Setting aside travel costs for detoured trucks, the primary cost of an HRGC crash is the injury or loss of life of the motor vehicles, including trucks, involved in these crashes. Data from the Railroad Safety Statistics Annual Report (FRA 2006) indicates that fatalities are very common in these crashes. The ratio between fatalities and crashes is .117, meaning that every 100 crashes would result in 11.7 fatalities; the relevant ratio for injuries is 0.332.

Most of these fatalities occur in motor vehicles rather than trains, and automobiles are much more common that trucks. We utilize the share of trucks and cars operating at the "mean HRGC" crossing. In other words, given that crashes are more likely at busier crossings, what are the average conditions at the sites where crashes would actually be expected to take place? This would be different (higher) than the average traffic flow patterns at all crossings. We utilize conditions at the mean HRGC crossing site throughout the analysis that follows during the remainder of the report.

At the mean HRGC crash site, approximately 2.7% of the traffic flow is truck traffic. We therefore assume that 2.7% of fatalities and injuries that occur in each crash would be in a truck. This suggests that each HRGC would yield 0.0032 fatalities and 0.0090 injuries among truck drivers, as seen in table 4.3 below. Table 4.3 shows the calculation of crash costs for trucks per HRGC crash. The cost of fatalities is $6.2 million per fatality according to the Office of Management and Budget. A cost of $141,000 per injury was developed by updating values from Thompson et al. (2001) to 2011 dollars. The expected crash cost per crash for trucks is $20,111.

Table 4.3 Crash Cost for Truck Drivers per HRGC Crash

Type	Likelihood	Cost	Cost Per Crash
Fatality	0.0032	$6,200,000	$19,840
Injury	0.0090	$141,270	$1,271
Total			$20,111

Source: FRA (2006) and Thompson et al. (2001).

Logistics costs arising from the 15 minute detours would be meaningful, but would be different than the major delays imposed on railways when tracks are shut after an at-grade highway-rail crash. Specifically, the short increase in time during a truck detour would be akin to the disruptions caused by traffic congestion. Literature is available on the value that truck operators or shippers place on time delays associated with congestion. These costs would include lost driver time, operating costs, as well as logistics costs. It was possible to isolate logistics costs in Miao et al. (2011). Those authors found that company drivers were willing to pay $61.56 more per hour to avoid short delays (30 minutes) than owner-operators, who would not consider the logistics costs for firms paying for the shipping. Similarly, Small et al. (1999) found that freight carriers calculated unexpected delays at $178.50 per hour more than planned travel. Finally, an hourly logistics cost of $79.64 is estimated based on Khattak et al. (2008), who conducted a survey of North Carolina shippers and receivers. We take a simple average of these survey-based estimates to yield an average hourly logistics cost from delays of $106.57 per hour.[3] These logistics costs are for a 15 minute delay of trucks impacted by the crash, in table 4.4 below. Seventeen trucks would be impacted by the crash given that we anticipate that the crash would cause a road and track closure of 4 hours, and that the daily truck travel at the mean HRGC crash site is 102. The total logistics costs would be $455.

Table 4.4 shows the total costs per HRGC crash including operating costs, crash costs, and logistics costs. The detour costs are $290 for trucks while the expected crash costs are $20,111 and the logistics costs are $455. The total costs are $20,856.

[3] Weisbrod *et al.* (2001) also identified "reliability costs" associated with congestion in four industries: agriculture, mining, manufacturing, and other/services. The author's, however, provided little information on the source for the estimates, and did not provide a way to weight the reliability costs by industry into an aggregate value.

Table 4.4 Total Cost for Trucks per HRGC Crash

Type	Cost Per Vehicle	Vehicles	Cost Per Crash
Detour	$17.00	17	$290
Crash			$20,111
Logistics			$455
Total			$20,856

Source: BBR Calculations

Chapter 5 Identification of Rail Economic Factors

This task is focused on identifying a rail company's economic factors that are common amongst HRGC crashes. Following the pattern for trucks, we first consider the costs that accompany delays caused by crashes; in this case, the delays caused by the closure of rail lines. Crash costs are considered next, including injuries or fatalities suffered by rail employees. Hazardous material release is another potential cost for the rail industry. Principal investigator Aemal Khattak has worked closely with Nebraska Hazmat response groups both during and before this research project. Finally, logistics costs are again considered, especially since HRGC's can impose large delays in the rail industry. Opportunities for detouring freight are limited so that railroads will tend to wait rather than detour. Further, delays will last the entire closure of the rail line during the clearing of the HRGC and any necessary investigation of the crash before trains can use the line again.

Another consequence is that measurement of delay costs focus on waiting rather than operating costs. Our literature review identified an operating cost for heavy unit trains of $1.19 per ton-mile in 1994 dollars (Forkenbrock 2001). This operating cost, however, is not relevant. The more relevant factor is the idling cost (or wait cost) for trains. As noted earlier, these include logistics costs. However, there is also the cost for a waiting train such as the time of employees and the fuel used while the train is idling. There are typically two employees per train so the idling time is the hourly wage and benefits of rail employees. This hourly rate per worker is $23.32 given the average hourly wage of $19.52 for train operators in May 2011 (U.S. Bureau of Labor Statistics) and the hourly benefit rate of $3.80 for train operators. The employee waiting costs per crash is therefore $46.64 times the average hours idling for all impacted trains. Further, we calculated that rail fuel costs are typically 24% of labor costs (Association of American

Railroads 2004), suggesting another $11.19 in costs while idling as train engines are typically left on while idling. This suggests a total idling cost per crash of $57.83 per hour times the average hours idling for all impacted trains.[4] There may be other costs associated with train idling (e.g., environmental costs) but we assume no cost. We also have no information on average damage costs to tracks and equipment from crashes. We assume an average waiting time of 4 hours for the delay. At our mean HRGC crash site, that will impact 11 trains. The total cost of an hour of waiting including employees and fuel is $57.83. This yields a total waiting cost per crash of $2,649.

There are also potential costs from hazardous materials spills. Hazardous materials are carried in approximately 10% of train trips, and information from FRA (2006) suggests that 4% of crashes involving trains carrying hazardous materials lead to release of hazardous materials. Therefore, 0.4% of crashes would involve the release of hazardous materials. There is an average evacuation of 206 persons per release of hazardous materials. The cost per evacuee is approximately $1,500 (Battelle 2001) so the total cost of evacuations per hazardous materials release is $309,600. However, as noted above only 0.4% of train crashes would involve the release of hazardous materials. As such, the average hazardous materials release costs per HRGC crash is $1,248.

Another primary cost of HRGC is the injury or loss of life of rail employees involved in these crashes. Data from the Railroad Safety Statistics Annual Report (FRA 2006) indicates that fatalities are common in train-involved crashes. The ratio between fatalities and crashes is 0.117,

[4] Forkenbrock (2001) indicates that the typical heavy freight train will have 4 engines and 100 rail cars. The Association of American Railroads (2010) indicates that the average rail engine (newly built or refurbished) costs approximately $2 million while the average rail car costs $25,000 (newly built or refurbished) suggesting a cost of $10.6 million for a new train. Assuming a 10% depreciation rate (the typical rail engine is refurbished every 10 years) yields an hourly depreciation cost (i.e., idling) of $121.20 for the entire train stock of engines and rail cars. However, we assume that the idling time is simply substituted for other down time with the train, so that there is no net time cost.

meaning that every 100 crashes would result in 11.7 fatalities. The relevant ratio for injuries is 0.332. Most of these fatalities occur in motor vehicles rather than trains. Approximately 10% of fatalities and injuries that occur in each crash would involve rail employees. This suggests that each HRGC would yield 0.012 fatalities and 0.033 injuries among rail employees, as seen in table 5.1 below. This table shows the calculation of crash costs for railways per HRGC crash. The cost of fatalities is $6.2 million per fatality according to the Office of Management and Budget. A cost of $141,000 per injury was developed by updating values from Thompson et al. (2001) to 2011 dollars. The crash cost per train crash is $77,498.

Table 5.1 Crash Cost for Railroad Employees per HRGC Crash

Type	Likelihood	Cost	Cost Per Crash
Fatality	0.012	$6,200,000	$72,809
Injury	0.033	$141,270	$4,689
Total			$77,498

Source: FRA (2006) and Thompson et al. (2001)

Estimates of logistics costs are based on the additional costs from permanently lost sales resulting from an extended closure of a major transportation corridor. The research team identified little publically available information in regards to rail freight delays in the United States but several examples of extended weather-related closures were available from the truck freight industry. These results are used as a substitute since truck and rail freight compete in similar markets, particularly in sectors such as agriculture and manufacturing. As noted by Forkenbrock (2001), 41% of truck transportation is competitive with rail transportation. Data from two multi-day closures in the State of Washington (Ivanov et al. 2008) in particular provided data on both permanently lost sales and increases in transportation costs due to paying and housing workers during delays. The survey focused on “transportation-dependent” industries, such as agriculture, manufacturing, and wholesaling.[5] The study found that the logistics costs for lost sales actually exceeded the delay costs for transportation providers. Logistics costs from permanently lost sales were 155.8% of the delay costs for transportation providers. Maze, Crump, and Burchett (2005) did not generate such specific estimates but did interview a number of transportation dependent businesses in Iowa regarding weather-related road closures and found that customers assessed fines of $500 to $600 for significantly late deliveries or reported costs of a similar amount. Potential costs from significantly delayed deliveries were even larger for selected customers, with perishable goods or a very time sensitive supply chain. These results are consistent with the findings of Ivanov et al. (2008) that logistics costs are significantly higher than delay costs, specifically 155.8% of delay costs for trucks.

However, this figure also should be adjusted for the fact that transportation costs are lower for rail transportation than for truck transportation. As a result, the ratio between logistics costs (which would be the same) and delay costs (which are lower) should rise. In particular, Forkenbrock (2001) found that truck operating costs per ton-mile where 7.07 times greater than rail operating costs.[6] Applying that ratio suggests that logistics costs for rail would be 1098.8% of delays costs. Given estimated delay costs of $2,649, the estimated logistics costs would be $29,205.

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[5] The study also surveyed on steps transportation dependent firms took in the aftermath of the closure to mitigate against lost sales and delays costs in the future should major closures occur. These mitigation efforts were just 4.7% of the actual loss due to permanently lost sales.

[6] Another way to consider this issue is that each train hauls much more freight than each truck, so more cargo will be impacted when a train is late than when a truck is late.

Table 5.2 shows the total costs per crash including delay costs, hazardous material costs, crash costs, and logistics costs. As noted above, the delay costs are $2,649 for railroads, while the expected train crash costs are $77,498 and the hazardous materials costs $1,248. The logistics costs are $29,205, making the total costs $110,600.

Table 5.2 Total Cost for Railroads per HRGC Crash

Type	Cost Per Crash
Delay	$2,649
Hazardous Materials	$1,248
Logistics	$29,205
Crash	$77,498
Total	$110,600

Source: BBR Calculations

Chapter 6 Identification of Driving Public Economic Factors

Economic factors for the driving public largely pertain to costs associated with operating small, medium, and large cars, as well as SUV's and vans. For the purposes of this chapter these categories as a group will be called automobile travel. In automobile travel, operating costs, ownership cost, operator time, and deaths and injuries all apply. Operator time is valued differently at leisure than at work.

We reviewed a number of articles and reports that calculated the relevant costs, including those in Miller et al. (1991) and Hall, Thompson, and Rosenbaum (2008), and those utilized in Thompson et al. (1997), Thompson et al. (2001), and Thompson (2003). The American Association of State Highway and Transportation Officials (AASHTO 2010) also provided information on various costs; in particular, operating and ownership costs.

Relevant cost information for ownership, operating, time, and crash costs are summarized in table 6.1. This table is analogous to table 4.2 in the earlier chapter on economic factors for trucks. AASHTO (2010) provided information on ownership and operating costs for various types of automobiles. Costs were averaged and updated to 2011 values based on the consumer price index between 2000 and 2011 (30.6%), following AASHTO (2010), and included in table 6.1 below. The cost includes all ownership and vehicle operating costs except for fuel. We assume that the average vehicle drives for 300 hours per year in order to determine ownership and operating costs, except fuel, on a per hour basis, which is $16.75. This amount is based on 15,000 miles per year at an average speed of 50 miles per hour.

Fuel costs per hour were calculated by determining the fuel costs per mile and again assuming an average speed of 50 miles per hour. Given the unpredictability of fuel prices, it was important to make the calculation flexible to accommodate current fuel prices, rather than using the averages in the AASHTO (2010) report. The calculation of fuel costs was based on an average annual price for regular unleaded of $3.55 during 2011 according to the Nebraska Energy Office, and an average 2009 fuel efficiency of 22.65 miles per gallon according to the Statistical Abstract of the United States 2011; it was assumed that this fuel efficiency also pertained to 2011. This fuel price and average mileage suggests fuel costs of $0.157 per mile in 2011. Applying 50 miles of travel per hour yields an hourly fuel cost of $7.84.

These costs do not include the cost of driver and passenger time. In leisure trips, the cost of driver time and passenger time is approximately 50% of the hourly wage, as in AASHTO (2010) and Thompson et al. (2001). Thompson et al. (2001) also found that the average occupancy for leisure trips was approximately 2.0. Time at work, like truck travel, is valued at the full compensation of workers, including wages and benefits, and occupancy of 1.0 is assumed. Work trips account for approximately 10% of all trips. Data from the U.S. Bureau of Labor Statistics indicate that the average hourly wage in Nebraska was $17.00 in May 2011. The average cost per hour for the average vehicle considering occupancy, wages, benefits and trip purpose was $17.37, as seen in table 6.1

The total cost per hour including fuel and driver time is $41.95 or $0.699 per minute of time spent traveling in a detour. Total costs per mile of use also are calculated again based on 50 miles per hour of travel. The total cost is $0.839 per mile.

Table 6.1 Costs Due to Vehicle Use

Category	Annual Cost Due to Use
Ownership and Operating Costs Per Hour, Excluding Fuel	$5,024
Hours Driven per Year	300
Cost per Hour of Use (excluding fuel and driver time)	$16.75
Fuel Cost per Hour	$7.84
Driver Cost per Hour	$17.37
Total Cost per Hour of Use	$41.95
Total Cost per Minute of Use	$0.699
Total Cost Per Mile of Use	$0.839

Source: AASHTO (2010).

We assume an average detour of 5 minutes for automobiles. Automobiles have more alternatives to trucks and many communities with highway rail at grade intersections have alternative crossings available. Based on a 5 minute detour, the average cost for detoured vehicles would be $3.50.

Setting aside travel costs for detoured automobiles, the primary cost of HRGC crash is the injury or loss of life of automobile occupants involved in these crashes. Data from the Railroad Safety Statistics Annual Report (FRA 2006) indicates that fatalities are common in these crashes. The ratio between fatalities and crashes is .117, meaning that every 100 crashes would result in 11.7 fatalities. The relevant ratio for injuries is 0.332. Most of these fatalities occur in motor vehicles rather than trains, and automobiles are much more common than trucks. At the mean HRGC crash site, 87.3% of fatalities and injuries would occur in an automobile.

This suggests that each HRGC crash would yield 0.102 fatalities and 0.290 injuries among automobile drivers and passengers, as seen in table 6.2 below. Table 6.2 shows the calculation of crash costs for automobiles per HRGC crash. The cost of fatalities is $6.2 million per fatality according to the Office of Management and Budget. A cost of $141,000 per injury was developed by updating values from Thompson et al. (2001) to 2011 dollars. As seen in table 6.2, the cost per crash for automobiles is $674,219.

Table 6.2 Cost for Automobile Drivers and Passengers per HRGC Crash

Type	Likelihood	Cost	Cost Per Crash
Fatality	0.102	$6,200,000	$633,274
Injury	0.290	$141,270	$40,945
Total			$674,219

Source: FRA (2006) and Thompson et al. (2001)

Table 6.3 shows the total costs per crash including operating costs, operator time and crash costs. At the mean HRGC crash site, 614 automobiles would be required to detour during the 4-hour period when the highway is closed. The detour costs are $2,146 for automobiles, while the expected crash costs are $674,219. Total costs are $676,365.

Table 6.3 Total Cost for Automobile Drivers and Passengers per HRGC Crash

Type	Cost Per Vehicle	Vehicles	Cost Per Crash
Detour	$3.50	614	$2,146
Crash			$674,219
Total			$676,365

Source: BBR Calculations

Chapter 7 Development of Methodology for HRGC Crash Cost Estimation

Economic factors identified in Chapters 4, 5 and 6 were utilized to develop a model of crash costs, including logistics costs, at highway-rail at-grade crossings in Nebraska. The model was a combination of engineering and economic factors. A frequency estimate for crashes was developed and the probability of an annual crash was estimated for all at-grade crossings based on highway and train traffic flows. Economic costs were then assigned to crashes based on operating, logistics, injury, and hazmat considerations. These costs, in turn, reflect Nebraska wage rates and prices. Estimates of the frequency of crashes were combined with per crash costs to determine the expected cost of highway rail at-grade crossing crashes at a particular crossing over the course of the year. These expected costs are also an estimate of the annual benefits that could be achieved by a project to remove the at-grade crossing and replace with an overhead bridge or an underpass. Expected annual benefits also can be used to calculate a present value for benefits over the lifetime of the investment.

Calculation of these annual costs was an important goal of this research, in large part because these cost estimates can be critical in guiding investment decisions. Crash costs at highway rail at-grade crossings can be avoided through investments to replace at-grade crossings with bridges or underpasses. The present value of expected annual crash costs are an important part of the benefits of these investments, and therefore, critical in the benefit cost calculations that influence highway investment decisions. However, note that a full benefit cost calculation would require other considerations besides crash costs. One would be time savings on a day to day basis. An investment in a bridge or an underpass to eliminate an at-grade intersection could save truck and auto-drivers time ensuring that vehicles no longer need to wait for trains traveling through an at-grade crossing in a community. At the same time, the construction of bridges or underpasses at one at-grade intersection often is accompanied by the closure of other at-grade intersections in the vicinity. This could increase the travel time, and distance, for some trips. These issues, however, were beyond the scope of the current report.

Finally, note that a companion spreadsheet was developed to assess the annual benefits and present value benefits from eliminating the potential for HRGC crash costs at each crossing. The spreadsheet contains a row for every at-grade crossing in Nebraska. Columns of data include engineering and economic factors that influence total expected crash costs at each at-grade crossing. Engineering factors include the traffic volumes for automobiles, trucks, and trains, estimates of the frequency of crashes, assumptions about the likely detour time and distance for automobiles and trucks, and delays for trains should a crash occur at each at-grade crossing. Engineering data vary by site, but the assumed detour distances, delays for trains, and economic and wage factors are the same as those used to calculate annual crash costs for the mean HRGC crash in tables 4.4, 5.2, and 6.3.

Results from those tables also can be used to calculate the expected annual savings and the lifetime present value from an investment that removes an at-grade crossing at the mean HRGC location. Summarizing the results from tables 4.4, 5.2 and 6.3, the cost of a crash at the mean crash site would be $805,675. The expected number of crashes per year given the train and motor vehicle traffic conditions at the mean crash site would be .03123 (i.e., one crash every 32 years). This suggests an expected annual benefit from eliminating the potential for a crash at the mean crash site of $25,164. The present value of that annual savings, assuming 1) constant annual savings, 2) a 30-year investment horizon, and 3) a 10% real discount rate, is $235,836.

7.1 The Frequency of Crashes

A key parameter estimate in our model is the frequency of crashes at each at-grade crossing. Our database was constructed by merging FRA's highway-rail crossing inventory data with 2007-2010 highway-rail reported crashes. These datasets along with relevant documentation are publically available from the FRA's Office of Safety Analysis website (accessed 02/01/2011): <http://safetydata.fra.dot.gov/OfficeofSafety/>.

The model estimation process involved first aggregating the four-year crash data file by the U.S. Department of Transportation Grade Crossing Identification Number (GXID). Next it was combined with the grade crossing inventory data file using GXID as the key to match crashes with their relevant crossings. This resulted in a file that provided four-year vehicular crash frequencies at each HRGC. This file was then limited to HRGCs with AADT greater than 500 and less than 5,000 vehicles per day to make it more relevant to HRGCs in Nebraska. A negative binomial model for expected four-year vehicular crash frequencies was estimated using NLOGIT (version 4.0) software. Readers interested in details of negative binomial model estimation and NLOGIT are referred to Greene (2008), while details of the database construction and model estimation are given in Appendix A. The following equation was estimated for the expected number of vehicular crashes at an intersection over a 4-year period.

$$\textit{Four-Year HRGC Crashes} = \textit{exponent}\ (-3.829 + 0.103*(\textit{AATD}/1000) + 0.029*\textit{Train Count}). \tag{7.1}$$

In the above equation AADT is the average daily motor vehicle traffic volume and Train Count is the average daily train traffic volume.

The estimated numbers were then divided by 4 to yield the estimated annual number of crashes. Given the non-linear nature of the above equation, the results were sensitive to extreme values and estimates were based on at-grade crossings where AADT for motor vehicles ranged between 500 and 5,000. The equation was used for all crossings with AADT of more than 500, and the AADT was capped at 5,000 for the purposes of estimating the number of crashes at each crossing. For at-grade crossings with AADT less than 500, the number of crashes per year was assumed to be 0.00001.

Chapter 8 Conclusion

This research provided a standardized methodology for assessment of crash costs at HRGCs in Nebraska. Avoided crash costs are the primary benefit of safety improvements. However, we also found savings in logistics costs. Throughout the research, we ran a scenario to simulate the mean HRGC crash; that is, the scenario was run where train and motor vehicle traffic conditions were at values that would be found at the mean crash site. At the mean crash site, we found that a crash, if it did occur, would have a total economic cost, including travel time, travel delays, crash costs, and logistics costs, of $805,675. The expected number of crashes per year at the mean crash site would be .03123 (i.e., one crash every 32 years). This suggests an expected annual benefit from eliminating the potential for a crash at the mean crash site of $25,164. The present value of that annual savings, assuming 1) constant annual savings, 2) a 30-year investment horizon, and 3) a 10% real discount rate, is $235,836.

More generally, in this project we developed a spreadsheet which can be used to calculate the economic costs of crashes at any Nebraska HRGC based on the AADT and detour time on the impacted roadway, and train traffic and length of delay on the railway. This spreadsheet is available for simulation purposes and can be paired with estimates on the likelihood of crashes to determine the full annual and present value lifetime benefits of improving the safety of at-grade rail-highway intersections.

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Appendix A Database Construction and Model Estimation

Database Construction:

The estimated model is for predicting four-year crashes at HRGCs and is based on publically-available FRA highway-rail crossing inventory and reported crash statistics for 2007-2010. Crash files for each year were downloaded and combined in Microsoft Excel (2010). Some crash records had missing GXID (grade crossing ID) or were labeled pending, or train yard, etc. These were deleted from the combined (2007-2010) crash file, along with those involving only pedestrians rather than motor vehicles, or those coded as "Other." This combined crash file was read in SPSS (Version 20) and aggregated by GXID so that for each grade crossing, crashes (each row) were added (sum function) and an ACC_SUM variable was created (each row represented a crash and when aggregated by GXID gave the number of crashes over the four years at each GXID). After sorting on GXID, this file was ready for matching to the grade crossing inventory file.

Grade crossing inventory data on public crossings was downloaded and read in SPSS. This file was also sorted on GXID to ensure matching with the combined crash file. Missing values of AADT and Train Count were coded as -999, the default value for missing data in NLOGIT (Version 4.0). With the inventory file active, the combined crash file was matched to it using GXID as the key variable (both files provided variables). The procedure did not use the lookup table function in this match.

The two files were matched with each other with the resulting file containing a large number of observations (inventory file observations plus unmatched observations). These unmatched observations were deleted from the file to obtain only matched observations. Variables from the crash files had significant missing values in the matched file because the majority of the grade crossings did not experience crashes during the four years. These were recoded into 0's. This combined file was then read in NLOGIT.

Model Estimation:

The reported model is based on observations that were limited to AADT>500 and AADT<5000 because this represents the range of AADT for nearly all Nebraska HRGCs. A simple negative binomial model was estimated for ACC_SUM, representing the sum of four-year crashes at each grade crossing. Independent variables used in the model, besides the constant, were AADT (average daily motor vehicle traffic volume in thousands) and Train Count (average daily train traffic volume). Output from the software, including the command used for model estimation, appears below.

```
--> REJECT;AADT<500$
--> REJECT;AADT>5000$
--> NEGBIN; LHS=ACC_SUM; RHS=ONE, AADT000,TRNCOUNT$


+---------------------------------------------+
| Negative Binomial Regression                |
| Maximum Likelihood Estimates                |
| Model estimated: Jul 30, 2011 at 00:35:14AM.|
| Dependent variable             ACC_SUM      |
| Weighting variable                None      |
| Number of observations           73049      |
| Iterations completed                11      |
| Log likelihood function      -11311.05      |
| Number of parameters                 4      |
| Info. Criterion: AIC =          .30979      |
|   Finite Sample: AIC =          .30979      |
| Info. Criterion: BIC =          .31030      |
| Info. Criterion:HQIC =          .30995      |
| Restricted log likelihood    -11875.51      |
| McFadden Pseudo R-squared     .0475314      |
| Chi squared                   1128.920      |
| Degrees of freedom                   1      |
| Prob[ChiSqd > value] =        .0000000      |
| NegBin form 2; Psi(i) = theta             |
+---------------------------------------------+
+--------+--------------+----------------+--------+--------+----------+
|Variable| Coefficient  | Standard Error |b/St.Er.|P[|Z|>z]| Mean of X|
+--------+--------------+----------------+--------+--------+----------+
 Constant|   -3.82961154       .04568211   -83.832   .0000
 AADT000 |     .10360484       .01717412     6.033   .0000   1.79419947
 TRNCOUNT|     .02963410       .00156658    18.916   .0000   8.59476516
---------+Dispersion parameter for count data model
 Alpha   |    6.61064224       .36303881    18.209   .0000
```