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September 30, 2014

TECHNICAL MEMORANDUM

TO: Gulf Coast Rail District (GCRD)

FROM: Texas A&M Transportation Institute (TTI) Multimodal Freight Transportation Programs (MFTP)

SUBJECT: **Technical Memorandum for Houston-Area Highway-Railroad Grade Crossing Impedance Model Update (Contract 83-2XXOA006)**

This Technical Memorandum summarizes the results of work completed by TTI for the Gulf Coast Rail District (GCRD) and other public sector stakeholders in the Houston Region regarding grade crossing impedance calculations at a number of crossings in the area. The TTI Highway-Railroad Grade Crossing Impedance Model (Impedance Model) calculates the societal costs of mobility, safety, and air quality impacts associated with vehicular traffic impedance at highway-rail grade crossings based upon area-specific traffic makeup, recent Average Daily Traffic (ADT) at the crossings, and observed or estimated rail traffic levels which determine crossing closure time. Calculated benefits in the model accrue at highway-rail grade crossings with the elimination of the interaction between vehicles and trains by either constructing grade separation structures or closing a crossing. The accumulated value of the benefits (avoided costs) equals the total societal cost of the highway-rail grade crossing over the projected analysis period. These benefits can then be compared with the costs associated with either grade separation or crossing closure to assess the overall value of undertaking such a project.

This technical memorandum discusses the evaluation of the impacts associated with the highest traffic volume roadways or highly observed impedance crossings in the eight-county region including and surrounding Harris County. The crossings identified for investigation either maintain daily traffic levels greater than 10,000 vehicles per day or are identified by the Gulf Coast Rail District (GCRD) as crossings significantly impacting the traveling public in the region.

Any questions regarding this technical memorandum may be addressed to the TTI project manager, Mr. Jeff Warner, at (979) 862-2915 or j-warner@tamu.edu.

Technical Memorandum:
Houston-Area Highway-Railroad Grade Crossing Impedance Model Update

Contract 83-2XXOA006
Texas A&M Transportation Institute (TTI)
Multimodal Freight Transportation Programs
September 30, 2014

EXECUTIVE SUMMARY

The Texas A&M Transportation Institute's Highway-Railroad Grade Crossing Impedance Model (Impedance Model) was applied to estimate the calculated the societal costs of mobility, safety, and air quality impacts associated with vehicular impedance at 132 highway-railroad crossing locations in the eight-county region including and surrounding Harris County. The crossings identified for investigation either maintain daily traffic levels greater than 10,000 vehicles per day or were identified by the Gulf Coast Rail District (GCRD) as crossings where blockage during train operations significantly impact the traveling public. Harris County has 105 of the crossing locations that were studied; Fort Bend County has 20 crossing locations; and Brazoria, Galveston, and Montgomery have the remaining seven crossing locations. The average trains per day is calculated as 19 trains per day, with the average delay per event calculated as 5:00.

The overall societal costs are comprised of the costs associated with vehicle delay, emissions, lost fuel, and crashes. Calculating the Net Present Value (NPV) with a 3% discount rate, the total societal costs exceed $1.3 billion at these crossings over the 25-year analysis period. Of this total, 75% of the costs relate to the delay associated with trains blocking the grade crossings. That accumulated delay also results in lost fuel, which represents almost 13% of the overall costs. The crash component accounts for 8% of the costs and the combined emissions costs make up slightly more than 2.5%.

Benefits accrue at highway-rail grade crossings with the elimination of the interaction between vehicles and trains by either constructing grade separation structures or closing a crossing. The accumulated value of the benefits (avoided costs) equals the total societal cost of the highway-rail grade crossing over the projected analysis period. These benefits can then be compared with the costs associated with either grade separation or crossing closure to assess the overall value of undertaking such a project.

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Houston-Area Highway-Railroad Grade Crossing Impedance Model Update

Contract 83-2XXOA006
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INTRODUCTION

This technical memorandum discusses the investigation into the impacts of the highest traffic volume roadways or observed impeded crossings in the eight-county region including and surrounding Harris County. The crossings identified for investigation either maintain daily traffic levels greater than 10,000 vehicles per day or were identified by the Gulf Coast Rail District (GCRD) as crossings where blockage during train operations significantly impacts the traveling public in the region.

The TTI Highway-Railroad Grade Crossing Impedance Model (Impedance Model) calculates the societal costs of mobility, safety, and air quality impacts associated with vehicular impedance at rail grade crossings. Benefits accrue at highway-rail grade crossings with the elimination of the interaction between vehicles and trains through grade separations and crossing closures, with the benefit value equaling the calculated overall societal cost.

MODEL CONCEPT

Traditional highway-railroad grade crossing impact models measure the impacts largely based on the overall daily vehicle and train counts. This general approach, utilizing readily available data, does provide a means to compare the calculated effect between grade crossings; however, it does not accurately produce information on when the trains are actually impeding the grade crossings throughout the day in relation to daily traffic cycles. TTI’s Impedance Model analyzes the impact on roadway traffic by vehicle type on an hourly basis, ordinarily utilizing detailed roadway and train traffic data collected in the field. Additional detailed calculations provide a thorough analysis of the total societal costs (e.g. mobility, safety, and air quality) associated with interruptions created by train activity at specific grade crossings. In addition to the hourly traffic volumes, the TTI model takes into consideration factors such as the hourly vehicle-type mix, roadway speed limit, number of lanes, capacity, and expected annual traffic growth.

For this particular analysis in the Houston region, a "snapshot" of train activity captured through the videotaping of crossing gate arm closure data over a 7-day period in March 2014, allowed for the calculation of daily train activity and the hourly delay created by the trains.

These intricate levels of detail by individual grade crossing and by specific train corridor often may produce dissimilar results compared to traditional grade crossing impact analyses. For example, two corridors with similar train activity may experience very different blockage levels if the trains are traveling at different train speeds. Also, overall impedance is impacted by the times of the train blockage and in relation to hourly traffic volumes which reflect peaks such as morning and evening work traffic. Because of these peaks and valleys in traffic levels, roadways on a corridor with train activity occurring during peak traffic travel times will have vastly greater delay times compared to a corridor with train activity occurring at off-peak traffic travel times. Even small differences between the numerous contributing factors can create large differences in the accumulation of calculated societal costs used in the model, so the desire for increased accuracy drives the need for more detailed and precise input information.

Unexpected differences in results may also be seen on crossing locations within the same corridor which, due to the numerous contributing factors, may produce results that are non-intuitive. Table 1 provides an example of two crossings located on the West Belt Subdivision. Each crossing has similar daily vehicular traffic and experience the same train activity; however, the overall results of the 25-year analysis are vastly different, when performing the economic evaluation with a 3% discount rate. One contributing factor is likely the expected annual growth rate at each location, with the expected growth rate for the Hutchins/Commerce location almost doubling that of Lyons. Other contributing factors could be the hourly vehicular volumes in relation to the hourly train blockage, vehicle-type distribution, and accident prediction levels. These factors compound over the 25-year analysis period.

Table 1. Example of Different Results for Two Similar Crossing Locations

Crossing Location	ADT	Trains per Day	Roadway Growth Rate	NPV 3%
Hutchins/Commerce	3,763	24	7.1%	38,493
Lyons	3,489	24	4.0%	8,444

MODEL OVERVIEW

The TTI Impedance Model has three key elements – a crash prediction model, an impedance model, and an emissions model. The model concept is presented in Figure 1. The crash prediction model utilizes the Federal Railroad Administration (FRA) accident prediction equations to estimate the overall number of accidents, fatality accidents, and injury accidents per year at each crossing. The impedance model estimates changes in vehicular operations - acceleration, deceleration, cruise, and idle durations - as a result of at-grade rail crossing blockages. The emissions model combines the changed vehicular operations with emission rates to determine the change in vehicular emissions as a result of the presence of trains at crossings.

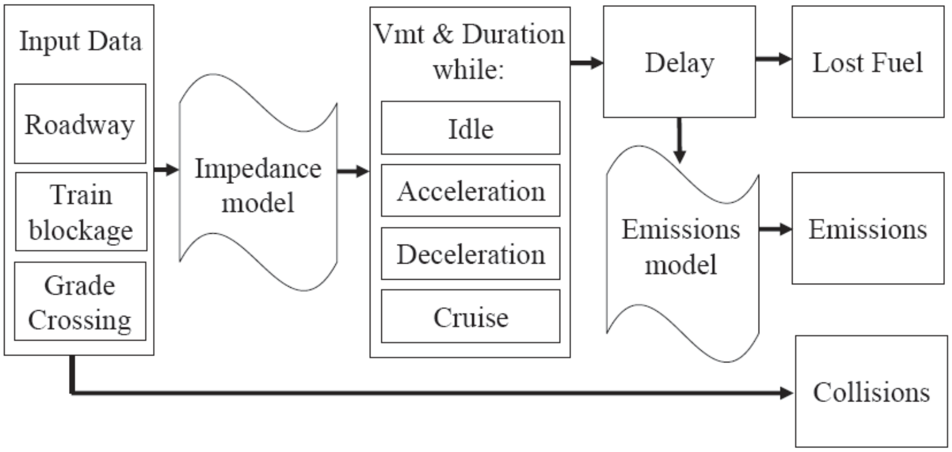

Figure 1. Simplified illustration of TTI's Impedance Model concept.

Crash Prediction Model

Safety benefits are equal to the expected costs of crashes at each grade crossing, with the predicted crashes following the FRA-developed formulas for predicted number of fatal, injury, and property damage-only crashes. Based on the guidance included within the *TIGER Benefit-Cost Analysis (BCA) Resource Guide,*[1] accident data was converted into the Abbreviated Injury Scale (AIS scale) before applying the recommended monetized values. The Value of Statistical Life (VSL) used is $9,200,000 per fatality (2013$) and the Property Damage Only (PDO) value is $3,682 per vehicle (2010$). Guidance associated with the VSL from *Guidance on Treatment of the Economic Value of a Statistical Life in the U.S. Department of Transportation*

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[1] http://www.dot.gov/policy-initiatives/tiger/tiger-bca-resource-guide-2014

Analyses (2013)[2] indicates that the VSL should increase at an annual growth rate of 1.07% per year for the analysis. Utilizing the Consumer Price Index (CPI), the VSL and PDO values were converted to constant dollars.

The FRA accident prediction equations, published in the *Railroad-Highway Grade Crossing Handbook*[3] and *GradeDec.Net Reference Manual*[4], predict the annual crashes, fatal crashes, and casualty crashes. The number of injury crashes is calculated by subtracting fatal crashes from the casualty crashes. The equations utilize a series of variables contained within the grade crossing inventory related to both roadway and railroad activity and crossing conditions. For this project, both the Texas and FRA grade crossing inventories were utilized to capture the most accurate data elements. The equations differ depending on the level of protection provided: passive warning, flashing lights, and gates and lights. The determination of the number of annual accidents utilizes the number of daily road vehicles and trains; number of day through-trains; maximum timetable train speed; number of main tracks; number of roadway lanes; and if the roadway is paved. Exposure, calculated using the number of vehicles and trains per day, used the actual data captured during the data acquisition activities in March 2014.

The equations to calculate the number of fatal and casualty crashes utilize additional variables captured from either the TxDOT or FRA grade crossing inventory, including number of through-trains per day; number of switching trains per day; if the crossing is urban or rural; and the number of railroad tracks. The estimated number of fatalities and injuries per fatality crash and the number of injuries per injury crash was calculated utilizing FRA data for the years 2009-2013. These values, included in Table 2, indicate that for fatality crashes there are over 1.1 fatalities and 0.48 injuries per crash and for injury crashes there are over 1.48 injuries per crash.

Table 2. Fatalities and Injuries per Crash Type, FRA 2009-2013 National Data

Description	Value
Fatalities per Fatal crash	1.12
Injuries per Fatal crash	0.49
Injuries per Injury crash	1.49

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[2] http://www.dot.gov/office-policy/transportation-policy/guidance-treatment-economic-value-statistical-life
[3] http://safety.fhwa.dot.gov/xings/com_roaduser/07010/index.htm
[4] http://www.fra.dot.gov/eLib/Details/L03769

Impedance Model

The impedance model estimates the number of vehicles delayed at each at-grade intersection due to train blockage taking into account the hourly crossing capacity, hourly volume, directional split, time period and duration of blockage. Equations then estimate the time spent idling, cruising, acceleration, and deceleration by vehicle type, at each crossing, by direction, by time period, using duration of blockage, average cruise speed, deceleration and acceleration rates by vehicle type.

Emission Model

In the emissions model, rates are converted from gallons/mile to gallons/hour by multiplying by the cruise speed (mph). The resulting equation estimates emissions for each crossing, by direction, time period, pollutant, and vehicle type, in grams, during train blockage (No Build). The same equation also estimates emissions with no blockage, (only cruising), hence the net additional emissions given train blockage can be estimated (Build). Figure 2 shows a time/speed diagram of a vehicle delayed by a train, along with the typical emissions during the train blockage event.

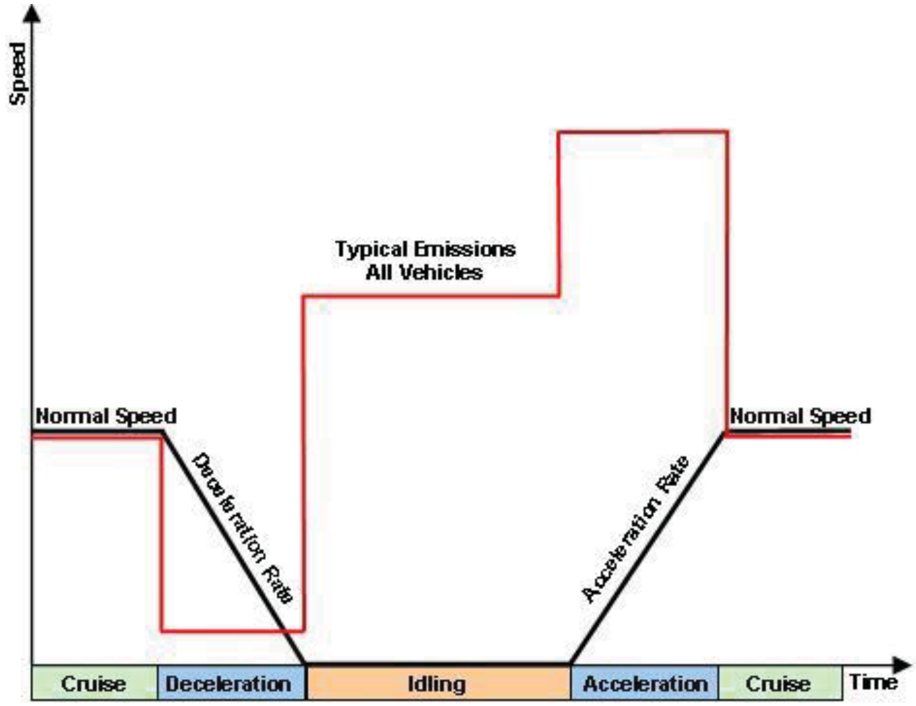

Figure 2 Typical emissions and speed regime vs. time during train blockage.

DATA ACQUISITION AND MODEL DEVELOPMENT

The following sections describe the data acquisition and model development utilized within the model.

Focus of Analysis

It was not the scope of this project to evaluate every highway-railroad grade crossing in the eight-county region including and surrounding Harris County, as was previously done during the larger Houston Region Rail Analysis conducted by TxDOT and GCRD. This project investigated only those crossings that either maintain daily traffic levels greater than 10,000 vehicles per day or that were identified by the GCRD as crossings with impedance significantly impacting the traveling public in the region.

Roadway Data

An initial cut to reduce the potential number of highway-railroad grade crossings to include in the analysis was conducted by using the most current TxDOT grade crossing inventory to identify those with roadway ADT levels greater than 8,000 vehicles per day. This assumed that some roadways listed in the most recent TxDOT inventory as near but under the 10,000 ADT threshold may have recently achieved levels greater than 10,000 ADT. To further reduce and finalize the number of grade crossings to a final set for analysis, the most current and accurate roadway data from the Houston region was used.

As part of this second cut, a hierarchy of data sources was developed. Generally, the hierarchy was to prioritize use of each source as follows:

- in-field data collected by GCRD for this study,
- previous GCRD traffic data,
- City of Houston traffic counts, and
- TxDOT grade crossing inventory ADT counts.

As input into the study, GCRD captured hourly roadway volume and vehicle classification data at 26 roadways. With most roadways having counts done for both directions, this resulted in a total of 48 counts. GCRD had previously collected hourly roadway and vehicle classification data for several Union Pacific (UP) West Belt Subdivision roadways, which were examined for this project. The City of Houston traffic counts, where available, provided hourly volumes but no vehicle classification breakdown. The TxDOT grade crossing inventory only maintains a total daily volume value with no directionality or time of day. Following the capturing of the most current roadway data, the crossings not meeting the 10,000 daily vehicles threshold and not on the GCRD list were eliminated from the analysis.

For roadways in which the hourly volumes were not collected, a generalized hourly volume developed by TTI's Transportation Modeling Program was utilized. The hourly distribution was specific to TxDOT Houston District counties, with a different, but similarly applied, distribution provided that is typical for TxDOT Beaumont District counties. The vehicle mix was divided into four time periods (overnight, AM peak, Midday, and PM peak) for four roadway types (rural restricted access, rural unrestricted access, urban restricted access, and urban unrestricted access). The vehicle classification categories are light duty vehicle, light duty truck, and heavy duty trucks, which are the categories required for the emissions model.

Roadway growth rates were provided by the Houston-Galveston Area Council (HGAC). TTI provided the list of crossings with the cross streets identified so that HGAC could identify the proper roadway link. HGAC provided 2014 and 2035 projected traffic levels. Using these levels, TTI calculated the compound average annual growth rate. Most of the remaining roadway data needed within the model components largely came from the TxDOT or FRA grade crossing inventories. This includes information on factors such as if the roadway operation is 1-way or 2-way, roadway speed limit, number of lanes, and level of grade crossing protection. The research team made efforts to confirm many of these values by examining aerial photographs or using the Street View function in Google Earth© maps.

Railroad Data

Train blockage time for the crossings in this analysis was captured during mid-March 2014 through video-capture of the time each crossing was blocked by the gate arms along most of the Houston-area railroad corridors. A total of 20 locations captured the seven days' worth of gate arm activated video data. This data provided both the delay time per hour caused by the train activity and also the number of trains per day.

In addition, the TTI Houston Office actively collects railroad activity along the US 90A corridor through Sugar Land, which parallels the UP Glidden Subdivision. That data was utilized for the appropriate at-grade highway-rail crossings along that corridor. A small number of crossings meeting the study criteria were along corridors where gate arm data was not collected. A process was developed to distribute hourly delay utilizing the day and night trains per day values listed in the TxDOT grade crossing inventory and an assumed value for delay per train event for these locations.

Table 3 contains the average number of trains per day and the calculated average delay per event for each subdivision. The first column indicates the number of locations along each corridor where gate arm data was collected. The trains per day was calculated based on the seven day total train events captured within the data. The value in the table is the average of each gate arm data value. The average delay per event for each gate arm data file is the average over every event. The value in the table represents the average between each gate arm data location.

Table 3. Overview of Gate Arm Data by Subdivision

Subdivision	Gate Arm Collection Locations	Average Trains per Day	Average Delay per Event
BNSF Galveston	1	15	2:15
BNSF Houston	1	7	3:23
East Belt	2	26	9:01
Eureka	1	6	2:53
Glidden	5	20	3:57
Popp	1	1	5:32
Terminal	6	24	5:01
UP Galveston	2	6	6:47
West Belt	2	25	7:21
Grand Total	**21**	**19**	**5:00**

It is expected that rail traffic will grow over the 25-year analysis period, with a single rail growth rate applied to every grade crossing. This value was developed by RL Banks and Associates, Inc. as part of another regional rail study sponsored by the GCRD. The value produced by that study and used in this project is 2.53%.

As with the roadway data, the remaining rail data came from the TxDOT and FRA grade crossing inventories, including such variables as the number of tracks and maximum timetable speed. These inventories were also used to calculate the percentage of daily through trains, daily switch trains, and daily daytime through trains. These percentages were multiplied by the daily trains per day collected by the gate arm data to calculate those values. The FRA grade crossing inventory maintains the number of crashes at each grade crossing over the past 5 years. This value was utilized for the crash prediction model.

Houston/Galveston/Brazoria (HGB) Area 2014 Summer Weekday Emission Rates

The TTI Transportation Modeling Program develops accurate, reliable methods and procedures for estimating mobile source emissions in regions throughout Texas. The Transportation Modeling Program assisted in this project in a variety of ways, perhaps most importantly in the development of mobile source emission rates specific for the types of vehicles found in the Houston area. The Houston-Galveston-Baytown (HGB) area county-level (Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller counties) 2014 summer weekday emission rates were developed using EPA's latest version of MOVES2010b (revised January 2013), along with local input data specific to the HGB area and MOVES defaults. The local data included the hourly average temperature and relative humidity, county-level vehicle age distributions, statewide diesel fractions, survey-based fuel formulations, and inspection and maintenance (I/M) program parameters. The MOVES emission rates for NOx were also adjusted to reflect the estimated effects of the Texas Low Emission Diesel Fuel (TxLED) Program. Using the VMT mix, the MOVES-based emission rates, which are by source use type (SUT)/fuel type combination, were combined into the three vehicle categories: light duty vehicles (LDV), light duty trucks (LDT), and heavy duty trucks (HDT).

Monetary Values

Monetization of the benefits utilized the values and techniques included within the *TIGER Benefit-Cost Analysis (BCA) Resource Guide,*[5] updated March 28, 2014, along with some additional sources. For this project, the time period of analysis was 25 years. Discount rates of 3% and 7% were applied to all evaluations with the exception that carbon dioxide calculations only use 3% as directed by the TIGER instructions. The following tables contain the monetary values and data associated with each benefit category. Table 4 provides the monetary values for the crash model component. Table 5 contains the listing of monetary values for the non-safety values, many of which are as outlined in the TIGER guidance.

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[5] U.S. DOT, *TIGER Benefit-Cost Analysis (BCA) Resource Guide,* Available: http://www.dot.gov/policy-initiatives/tiger/tiger-bca-resource-guide-2014 Accessed: September 2014.

Table 4. Monetary Values for Safety Benefits

Type	Sub-Type	Value (2013)	Value ($April 2014)
Fatality (per person)	NA	$9,200,000	$9,272,034
Injury (per person)	AIS 1 (Minor)	$27,600	$27,816
	AIS 2 (Moderate)	$432,400	$435,786
	AIS 3 (Serious)	$966,000	$973,564
	AIS 4 (Severe)	$2,447,200	$2,466,361
	AIS 5 (Critical)	$5,455,600	$5,498,316
Property Damage Only (per crash)	No Injury	$3,682	$3,964

Table 5. Monetary Values for Other Benefits

Type	Value	Year	Source	$April 2014
Nitrogen Oxides (NOx)	$6,700/SHORT ton	2010	*TIGER BCA Resource Guide (2014)* http://www.dot.gov/policy-initiatives/tiger/tiger-bca-resource-guide-2014 Accessed April 1, 2014	$7,214/ST
Volatile Organic Compounds (VOC)	$1,700/SHORT ton	2010	*TIGER BCA Resource Guide (2014)* http://www.dot.gov/policy-initiatives/tiger/tiger-bca-resource-guide-2014 Accessed April 1, 2014	$1,830/ST
Carbon Dioxide (CO2)	Varies by future year; $/METRIC ton	2007	*TIGER BCA Resource Guide (2014)* http://www.dot.gov/policy-initiatives/tiger/tiger-bca-resource-guide-2014 Accessed April 1, 2014	$ /MT; see Table 7 below
Fuel Price	$3.418/gal (Gas) $3.804/gal (Diesel)	March 31, 2014	*Weekly Retail Gasoline and Diesel Prices, Gulf Coast (PADD 3)*. U.S. Energy Information Administration. http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_r30_w.htm Accessed Feb. 24, 2014	$3.418/gal (Gas) $3.804/gal (Diesel)
Vehicle Occupancy	1.25 persons/vehicle	2011	*TIGER BCA Resource Guide (2014)* http://www.dot.gov/policy-initiatives/tiger/tiger-bca-resource-guide-2014 Accessed April 1, 2014	1.25 persons/vehicle
Value of Time	$12.81/person-hr (local all purposes) $25.42/vehicle-hr (truck drivers)	2012	*TIGER BCA Resource Guide (2014)* http://www.dot.gov/policy-initiatives/tiger/tiger-bca-resource-guide-2014 Accessed April 1, 2014	$13.10/person-hr (LV & LDT) $25.99-hr (HDT)
Public Discount Factor	3% and 7%	NA	*OMB Circular A-4, Regulatory Analysis, September 17, 2003*. Office of Management and Budget. http://www.whitehouse.gov/omb/circulars_default/ Accessed April 1, 2014 *TIGER BCA Resource Guide (2014)* http://www.dot.gov/policy-initiatives/tiger/tiger-bca-resource-guide-2014 Accessed April 1, 2014	3% and 7%

Table 6 contains the Consumer Price Index (CPI) values, which allowed for the normalization of financial data to the same time period (2014$). Table 7 contains societal cost of carbon dioxide for the 25 years utilized for this project.

Table 6. CPI Values used to Update to April 2014$

CPI	Year/Date	Source
208.974	2007	*Consumer Price Index (CPI), CPI Detailed Report – Data for February 2014.* Bureau of Labor Statistics. http://www.bls.gov/cpi/ Accessed April 2, 2014 Pg 88 Table 24. Historical Consumer Price Index for All Urban Consumers (CPI-U): U. S. city average, all items
218.056	2010	
224.939	2011	
229.594	2012	
232.957	2013	
233.916	01/2014	
234.781	02/2014	

Table 7. Social Cost of Carbon (CO2) Monetized Values

Year	3% SCC (2007$)	3% SCC (2014$)	Year	3% SCC (2007$)	3% SCC (2014$)
0	36	40	13	49	55
1	37	42	14	50	56
2	38	43	15	51	57
3	39	44	16	52	58
4	40	45	17	52	58
5	42	47	18	53	60
6	43	48	19	54	61
7	43	48	20	55	62
8	44	49	21	56	63
9	45	51	22	57	64
10	46	52	23	58	65
11	47	53	24	59	66
12	48	54	25	60	67

Source: *TIGER BCA Resource Guide* (2014, http://www.dot.gov/policy-initiatives/tiger/tiger-bca-resource-guide-2014, Accessed April 1, 2014.

MODEL RESULTS

This section presents the result of the analysis of the 132 examined crossing locations in the study area. A crossing location could be a single grade crossing or a set of grade crossings. Working with the GCRD, it was determined that in some situations grade crossing improvements would only occur if a set of crossings were improved, not just a single crossing. These usually included locations where each direction of a roadway, slightly spatially separated, had different grade crossing identification numbers but, if upgraded, would entail a single project. Therefore, for this study these sets of crossings are reported as a single grade crossing location. Only one crossing location involved more than two crossings, and that was the Griggs-Long-Mykawa complex of crossing at the intersection of the Glidden and Mykawa Subdivisions. In total, 143 highway-railroad grade crossings were included in the study.

The overall societal costs are comprised of the costs associated with vehicle delay, emissions, lost fuel, and crashes. Figure 3 demonstrates the cost components breakdown for all the crossings, using the NPV values with the 3% discount rate. Over 75% of the overall societal cost relates to the delay associated with trains blocking the grade crossings. That delay results in lost fuel, which represents almost 13% of the overall costs. Combined the emissions costs make up slightly more than 2.5%, with the crash component accounting for the remaining 8%.

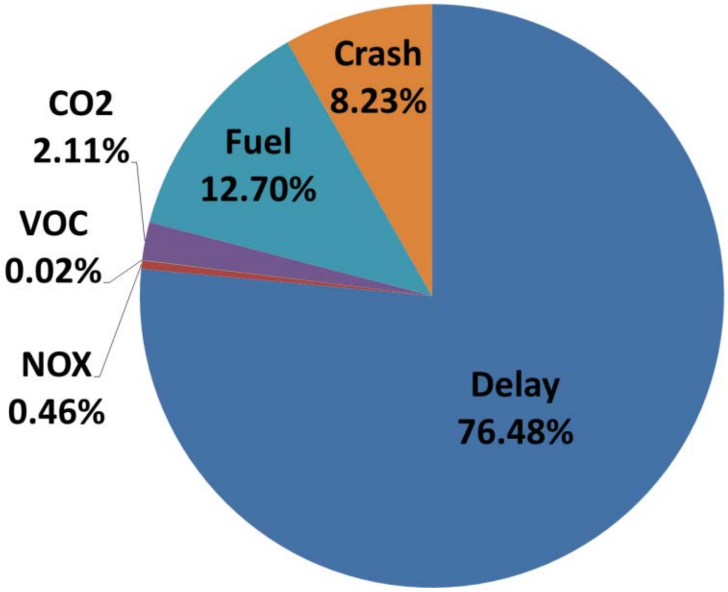

Figure 3. Breakdown of cost components.

As directed by the TIGER application guidance, discount rates of 3% (NPV 3%) and 7% (NPV 7%) were utilized in the financial calculations. Table 8 contains the breakdown of societal costs for crossings in the eight-county region that met the criteria for this project. Combined, the total societal costs associated with the 132 grade crossing locations reach almost $1.3 billion (NPV 3%) and $760 million (NPV 7%).

Table 8. Breakdown of Overall Societal Costs

# of Crossings	NPV 3% ($1000)	NPV 7% ($1000)
132	1,289,041	759,704

Table 9 contains the breakdown of societal costs by railroad subdivision operating through the region. The most study highway-rail grade crossing locations reside on the Glidden Subdivision (23), which operates through both Harris and Fort Bend Counties, followed by the BNSF Houston Subdivision (21) and UP Galveston Subdivision (17). The Glidden Subdivision accounts for $444.8 million (NPV 3%) and $261.0 million (NPV 7%) in societal costs, followed by the West Belt ($307.4 million, NPV 3%; $25.6 million, NPV 7%) and the Terminal Subdivision ($175.4 million, NPV3%; $14.6 million, NPV 7%).

Table 9. Breakdown of Overall Societal Costs by Railroad Subdivision

Subdivision	# of Crossings	NPV 3% ($1000)	NPV 7% ($1000)
Glidden	23	444,791	261,007
West Belt	12	307,397	173,651
Terminal	14	187,525	114,178
East Belt	5	157,383	93,133
BNSF Houston	21	38,781	24,111
Eureka	14	30,415	18,902
BNSF Galveston	9	26,649	16,209
PTRA	1	22,720	13,705
Popp	9	18,927	11,286
UP Galveston	17	18,771	11,630
Palestine	1	9,645	5,953
Strang	3	9,517	5,706
Navasota	2	8,312	5,186
Baytown	1	8,208	5,045
Grand Total	**132**	**1,289,041**	**759,704**

A further breakdown in the cost components for the top three subdivisions is included in Table 10. The three subdivisions have noticeable differences in the breakdown of societal costs. The Glidden Subdivision has the highest percentage of societal costs associated with crashes between the three subdivisions, with 10.0%. This is compared to the West Belt Subdivision with only 1.4%. The West Belt Subdivision has the highest level of societal costs associated with vehicle delay between the three subdivisions with 84.6%. This is followed by the Terminal Subdivision with 79.2% and Glidden Subdivision with 73.5%.

Table 10. Societal Costs Breakdown for the Top 3 Subdivisions (NPV 3%)

Subdivision	Delay ($1000)	Emissions ($1000)	Fuel ($1000)	Crash ($1000)	Total ($1000)
Glidden	327,055 (73.5%)	11,082 (2.5%)	61,954 (13.9%)	44,700 (10.0%)	444,791
West Belt	260,067 (84.6%)	8,788 (2.9%)	34,127 (11.1%)	4,416 (1.4%)	307,397
Terminal	148,433 (79.2%)	4,774 (2.5%)	22,555 (12.0%)	11,763 (6.3%)	187,525

To assist in possibly explaining these numbers Table 11 provides the average number of trains per day and average delay per train event for the three subdivisions. The West Belt Subdivision experienced the longest delay per event at 7 minutes 21 seconds and average number of trains per day. The smaller delay per event variation along the West Belt would indicate that trains operate fairly consistent over the corridor. Both the Glidden and Terminal Subdivisions experience a wider variation in delay per event. Some roadway examples include:

- Glidden Subdivision
    - Kirkwood – 2:47 average delay per event
    - Griggs/Long/Mykawa – 8:57 average delay per event
- West Belt Subdivision
    - Cullen/Leeland – 6:25 average delay per event
- Terminal Subdivision
    - Richmond – 2:40 average delay per event
    - Sawyer – 4:07 average delay per event

Table 11. Characteristics for the Top 3 Subdivision

Subdivision	# of Crossings	Average Trains per Day	Average Delay per Event (min/max)
Glidden	23	20	3:57 (2:14/10:31)
West Belt	12	25	7:21 (6:25/8:18)
Terminal	14	24	5:01 (2:40/9:07)

The top 25 crossing locations, ranked by the total societal costs, are included in Table 12 (NPV 3%) and Table 13 (NPV 7%). The top 25, in both tables, account for approximately 67% of the total societal costs associated with the 132 crossing locations analyzed.

Table 12. Top 25 Study Area Grade Crossing Location Societal Costs (NPV 3%)

Rank	County	Subdivision	Street	NPV 3% ($1000)
1	Harris	West Belt	Cullen/Leeland	66,337
2	Harris	Glidden	Griggs/Long/Mykawa	59,814
3	Harris	East Belt	Wallisville	54,092
4	Harris	East Belt	Lyons	44,821
5	Fort Bend	Glidden	FM 359	44,675
6	Harris	West Belt	Hutchins/Commerce	38,493
7	Fort Bend	Glidden	Dairy Ashford Way	37,425
8	Harris	West Belt	Milby	36,780
9	Harris	Glidden	Fondren Rd.	36,716
10	Fort Bend	Glidden	Kirkwood Rd.	35,174
11	Harris	West Belt	York/Sampson	35,168
12	Fort Bend	Glidden	South Gessner Rd.	34,242
13	Fort Bend	Glidden	Eldridge/FM 1876	33,892
14	Fort Bend	Glidden	Collins/FM 3155	30,914
15	Harris	Terminal	Durham St./Shepherd St.	29,878
16	Harris	West Belt	Nance	29,102
17	Harris	West Belt	Quitman	28,514
18	Harris	East Belt	Harrisburg	28,186
19	Harris	Glidden	Hillcroft St.	26,401
20	Harris	Glidden	Chimney Rock Rd.	25,551
21	Fort Bend	Glidden	Reed Rd.	23,362
22	Harris	PTRA	Federal	22,720
23	Harris	Terminal	Westheimer St.	22,313
24	Harris	West Belt	Runnels	21,713
25	Harris	West Belt	Collingsworth	20,612
			Grand Total	**1,289,041**