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Safety at Highway-Railroad Crossings:
A Case Study of the Austin-San Antonio Corridor

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Safety at Highway-Railroad Crossings:
A Case Study of the Austin-San Antonio Corridor

by

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Report

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Dedication

For the love of trains.

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Thanks to my soul mate Ben for taking care of me while on this adventure called grad school. Thanks to my family for their pep talks to keep me going. And thanks to all those at UT, students and faculty, who challenged me to learn, have fun, and ultimately to become a better person.

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Abstract

Safety at Highway-Railroad Crossings: A Case Study of the Austin-San Antonio Corridor

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For over a decade proposals for connecting the metropolitan areas of Austin and San Antonio, Texas via passenger rail have been studied. In the Texas Department of Transportation's *2010 Rail Plan* several ideas, including high-speed rail, regional Amtrak service, and a new passenger rail service have been proposed as a means to provide an alternate mode of transportation along the I-35 corridor. Union Pacific Railroad currently owns and operations a rail line that connects the Austin and San Antonio metropolitan areas; each of the passenger rail projects proposes sharing this corridor with Union Pacific. A literature review reveals that a key factor in negotiating with a freight railroad for shared use of a corridor is safety. One element of the safety risk analysis is the evaluation of at-grade highway-railroad crossing. This study discusses the Austin-San Antonio corridor, its current mobility challenges and the proposed passenger rail projects.

It then discusses rail safety as expressed in the literature and provides background about safety at highway-railroad crossings. Crossing inventory and accident data, as maintained by the Federal Railroad Administration (FRA), is then analyzed using regression modeling in an attempt to better understand the relationship between the physical and operational characteristics of highway-railroad crossings and accidents on corridors shared by freight and passenger rail. It analyzes a five-year accident history (2005 to 2009) from of a sample of shared use highway-rail crossings throughout the US. The findings are then used to analyze the at-grade highway-railroad crossings along the Austin-San Antonio corridor. And finally, the implications of the findings are discussed. The findings of this report recommend that characteristics of the built environment such as land use, number of traffic lanes, and function classification of the roadway should be considered when assessing accident risk at highway-railroad crossings. In addition, this analysis reveals the need for a way to better measure safety risks at private highway-railroad crossings.

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Introduction

The cities of Austin and San Antonio are two growing metropolitan areas in Central Texas. Many researchers have argued that these metropolitan areas are interconnected and interdependent on many levels. Lang and Dhavale connect the two cities as part of the I-35 megaregion, which connects the San Antonio, TX metropolitan area to the Kansas City, MO metropolitan area along the interstate (Lang and Dhavale 2005). And, the Regional Planning Association proposes the Texas Triangle megaregion which links San Antonio, Austin, Dallas and Houston (RPA 2006). Megaregions have been argued to be better prepared to compete in a globalizing economy as they are a "massing together of talent, productivity, innovation and markets" (Florida 2008), however growth into a megaregion come with its challenges; one of which is maintaining a transportation network for the movement of people and goods. The major transportation corridor linking Austin and San Antonio, Texas is Interstate 35 (I-35). This corridor has experienced rapid growth in population and employment in the past decade and the existing transportation infrastructure is currently experiencing congestion and reduced mobility. Related to these issues are increasing concerns about safety and traffic fatalities on the I-35 and degraded air quality within the region. For over a decade proposals to connect the metropolitan areas of Austin and San Antonio via passenger rail have been put forth and studied. In the Texas Department of Transportation's (TxDOT) *2010 Rail Plan* several ideas, including high-speed rail, regional Amtrak service, and a new passenger rail service have been proposed as a means to provide an alternate mode of transportation in the region. Chapter 1 will provide a background of the Austin-San Antonio corridor and the current mobility challenges. It will also discuss the passenger rail projects that are in TxDOT's *2010 Rail Plan*.

Each of the passenger rail proposals in the TxDOT plan is considering the feasibility of utilizing the existing rail infrastructure that is owned and operated by Union Pacific. Among the many factors discussed when negotiating a track sharing agreement, safety is critical. Agencies that propose to add passenger rail service to a corridor owned by a freight rail company must be in a position to discuss a plan for maintaining the safety of the line. One element of the safety risk analysis process is the evaluation of at-grade highway-railroad crossings. At-grade highway-rail crossings are unique in that they are the intersection of two distinct transportation systems which differ in the physical characteristics of the infrastructure upon which they travel as well as their operations. When in conflict, these differences can result in collision and are thus a safety hazard for both rail and road travelers.

Texas does not have a stellar record of safety at highway-railroad crossings. From 2007 to 2009 the state of Texas has been ranked number 1 in the nation for the number of accidents at at-grade crossings and number two in fatalities (TxDOT 2010b). This may seem intuitive at first glance due to the size of Texas, however smaller states like Illinois and Indiana are also in the top five; this suggests that safety at highway-railroad crossings has national interest and significance and warrants particular attention from researchers, practitioners, and policy makers and regulators. Chapter 2 will discuss rail safety as expressed in the literature and by railroads and it will provide background about safety at highway-railroad crossings and their regulation.

The Federal Railroad Administration (FRA) is the arm of the U.S. Department of Transportation responsible for regulating heavy rail safety.[1] The FRA Office of Safety Analysis compiles and maintains safety records for highway-railroad crossings which include information about the operational and physical characteristics of the crossings and well as a log of accidents at these crossings dating back to 1970. This study will investigate these datasets with the intent of identifying factors that influence accidents at highway-railroad crossings, with a focus on those crossings that are currently shared by freight and passenger rail. The analysis will be two-fold; first it will look at a sample of shared use highway-rail crossings throughout the US and identify national trends, and then the findings of the national dataset will then be compared with the dataset for the Austin-San Antonio (ASA) corridor. A five-year accident history, from 2005 to 2009 will be used as the independent variable in the analysis and a set of 41 physical and operational characteristics will be analyzed as dependent variables. A linear regression model will be used to identify relationships between a five-year accident history and the dependent variables. Chapter 3 begins with a discussion of the methodology and assumptions used in the modeling effort; it then discusses the dataset and variables considered. The national dataset modeling results are presented and analyzed, and then compared to the ASA corridor.

Per the Rail Safety Improvement Act of 2008, the top 10 states for the number of fatal accidents at highway-rail crossings are required to conduct accident prevention studies and develop a 5-Year Action Plan for reducing fatalities by August 2011 (TxDOT 2010b). A 2003 to 2007 study conducted in the state of Texas for all highway-rail

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[1] The Federal Transit Agency is responsible for highway-rail grade crossings used by public transit systems such as subways, light rail, monorail, trolley and people mover transportation.

crossings revealed that 63% of the highway-railroad crossings that experienced more than one accident in this timeframe were equipped with train-activated warning devices and 41% of which had flashing lights and/or gates. As such those crossings with flashing lights and/or gates that have experienced multi-collisions will be included in the annual selection of crossings for improvement under the federal railroad signal program. (TxDOT 2010b). The analysis of the FRA datasets will attempt to show variables other than flashing lights and/or gates can be used as indicators of safety risks at highway-railroad crossings. Chapter 4 will touch upon some of the implications of the findings of this report.

Chapter 1: The Austin-San Antonio Corridor and its Mobility Challenges

The I-35 corridor in Texas stretches from Laredo in the south, through the cities of San Antonio, New Braunfels, San Marcos, Austin, Georgetown, Temple, Waco, and the Dallas/Ft. Worth area, before it crosses northward to Oklahoma City and continues on through the U.S. to the Canadian border. It is a major transportation corridor that was developed around the old Missouri Pacific (MoPac) rail line (now Union Pacific), which was constructed over 120 years ago. In its history, the MoPac Railroad serviced both freight and passenger travel. Passenger rail service was eventually displaced by the development of the automobile and construction of the I-35 corridor. Today the Austin San Antonio rail corridor is predominantly used by freight trains with approximately 34 daily trains. In addition, the rail corridor is used by Amtrak with one northbound and one southbound daily passenger train. The I-35 is now the major transportation facility that connects the ASA region; it is largely relied upon for commuter and intercity travel and it is a critical link for the through movement of freight. Since the signing of the General Agreement of Trade and Tariffs with Mexico in 1986, and later the North American Free Trade Agreement with Mexico and Canada in 1994, freight traffic has more than doubled on the I-35 and is anticipated to continue to grow. According to a 2003 study conducted by the Lone Star Rail District, truck freight demand has grown at an annual rate of 2 percent per year in the nation, 6 percent per year in the State of Texas and almost 15 percent along the ASA corridor (ASAICRD 2003). The I-35 corridor links to Mexico at the Port of Laredo, Texas. Table 1 shows the number of loaded truck and rail containers that enter the U.S. at the Port of Laredo between 1997 and 2009.

Mode	**1997**	**1999**	**2001**	**2003**	**2005**	**2007**	**2009**	**1997 to 2009 Change**
Truck	447,545	756,045	757,574	825,626	977,353	1,009,706	924,941	106.7%
Rail	84,488	131,798	187,479	197,684	197,337	189,244	122,831	45.4%
Total Containers	532,033	887,843	945,053	1,023,310	1,174,690	1,198,950	1,047,772	96.9%

Source: (BTS 2010)

Table 1: Growth in the Number of Freight Containers Entering the U.S. at the Port of Laredo

GROWTH OF THE AUSTIN-SAN ANTONIO REGION AND TRANSPORTATION IMPACTS

The need for passenger rail service in the ASA corridor arises from a historic and continuing trend in population and employment growth within the Austin and San Antonio metropolitan areas and increase in demand on the existing transportation infrastructure.

Between 1990 and 2005 the population of the Austin metropolitan area has grown 55% and vehicle miles traveled has increased by 77%. In the San Antonio metropolitan area the growth has been 16% and 84% respectively (2030 Committee 2009). The improvement of highway infrastructure; however, has not kept pace with this level of growth with only a 36% increase in lane miles added to the Austin metropolitan area and 21% additional lane miles added in San Antonio (Schrank and Lomax 2009, Schrank and Lomax 2005). Based on a study conducted by the Federal Highway Administration (FHWA) in 1999, the stretch of I-35 between Austin and San Antonio contained the highest levels of automobile related fatalities, the worst congestion, the slowest average driving speed, the lowest levels of service, and the highest levels of highway related pollution in the nation. Based on this study, if capacity were increased on I-35 alone, the 6-lane freeway would need to be expanded to 18 lanes by 2025 to accommodate the increasing demand (FHWA 1999). TxDOT has studied options to increase I-35's capacity along this corridor for nearly three decades. Because expanding the I-35 highway to 18 lanes through existing urban areas along the corridor is overly constrained by costs, environmental and social issues, as well as right-of-way issues, meeting the future demand for transportation facilities is challenged.

By 2035, the total population in ASA region is expected to increase to over 5 million, more than double the 2000 population. And, almost 3 million employees will be working in the region by 2035 which equates to an increase of more than 125 percent from 2000 (CAMPO 2010, SA-BC MPO 2009). Table 2 and Table 3 highlight the past and forecasted growth in population and employment for the five-county ASA region.

County	1950	1960	1970	1980	1990	2000	2035 Forecasted	2000-2035 Change
Bexar	500,460	687,151	830,460	988,800	1,185,394	1,392,931	2,149,142	54.3%
Comal	16,357	19,844	24,165	36,446	51,832	78,021	267,876	243.3%
Hays	17,840	19,934	27,642	40,594	65,615	97,589	371,200	280.4%
Travis	160,980	212,136	295,516	419,573	576,407	812,280	1,555,300	91.5%
Williamson	38,853	35,044	37,305	76,521	139,551	249,967	1,026,500	310.7%
Total	734,490	974,109	1,215,088	1,561,934	2,018,798	2,630,788	5,370,018	104.1%

Source: (US Census Bureau 2000a, US Census 1980, CAMPO 2010, SA-BC MPO 2009)

Table 2: Historical Regional Population Growth and 2035 Forecasts

County	1990	2000	2005	2015	2025	2035 Forecasted	2000-2035 Change
Bexar	497,202	595,911	731,325	902,923	1,008,160	1,162,044	95.0%
Comal	23,199	36,319	34,269	49,993	67,703	98,330	170.7%
Hays	30,737	50,484	41,000	66,200	97,800	137,300	172.0%
Travis	302,536	441,161	536,900	707,200	843,500	1,026,500	132.7%
Williamson	71,243	129,192	101,500	165,700	253,000	400,300	209.8%
Total	924,917	1,253,067	1,444,994	1,892,016	2,270,163	2,824,474	125.4%

Source: (US Census Bureau 2000c, US Census 1990c, CAMPO 2010, SA-BC MPO 2009)

Table 3: Past and Forecasted Regional Employment Growth

The US Census Bureau gathers data about commuting patterns and trends, including where people live and work, and how long it takes them to reach their work destination from home. Table 4 shows the commuting patterns along the ASA corridor. The percentages represent only those that live and work in the five-county region; some people who live in the five-county region work in other parts of Texas as well as outside the state.

Live In	**Work In**									
	Bexar County		**Comal County**		**Hays County**		**Travis County**		**Williamson County**	
	1990	2000	1990	2000	1990	2000	1990	2000	1990	2000
Bexar	99.5%	98.7%	0.3%	0.7%	0.1%	0.1%	0.2%	0.4%	0.0%	0.0%
Comal	28.5%	34.2%	66.5%	58.3%	2.8%	4.5%	2.1%	2.9%	0.1%	0.1%
Hays	2.3%	1.8%	3.4%	2.4%	57.2%	52.6%	36.6%	41.8%	0.5%	1.5%
Travis	0.2%	0.2%	0.0%	0.0%	0.6%	0.8%	97.0%	93.2%	2.2%	5.8%
Williamson	0.2%	0.2%	0.0%	0.0%	0.2%	0.3%	58.6%	53.9%	40.9%	45.7%

Source: (US Census Bureau 2000b, US Census Bureau 1990b)

Table 4: Commuting Patterns – ASA Counties along the I-35 Corridor

In looking at the change between commuting patterns between 1990 and 2000, one will note that, with the exception of Williamson County, a greater share of commuters are traveling outside their home county for work. This pattern suggests that workers are traveling further for employment within the region and are likely to be on the roadway longer. Table 5 substantiates the increase in travel to work with details about reported travel time to work from the five-county region around the study area.

Commute Time to Work	**Live In**									
	Bexar County		**Comal County**		**Hays County**		**Travis County**		**Williamson County**	
	1990	2000	1990	2000	1990	2000	1990	2000	1990	2000
Less than 15 minutes	25.1%	23.2%	36.7%	28.0%	33.6%	28.8%	29.6%	25.0%	25.6%	21.6%
15 to 29 minutes	46.6%	45.1%	27.7%	28.7%	27.9%	27.5%	47.4%	43.5%	32.6%	32.3%
30 to 44 minutes	20.7%	22.3%	17.4%	22.9%	22.0%	21.5%	16.6%	21.1%	27.3%	26.8%
45 to 59 minutes	4.1%	4.9%	10.5%	11.9%	10.6%	12.8%	3.4%	5.6%	9.7%	12.3%
60 to 89 minutes	2.0%	2.5%	5.5%	6.0%	4.4%	7.1%	1.8%	3.1%	3.2%	5.2%
90 minutes or more	1.5%	2.0%	2.3%	2.5%	1.6%	2.3%	1.2%	1.6%	1.6%	1.7%

Source: (US Census Bureau 2000d, US Census Bureau 1990d)

Table 5: Commute Time to Work – 1990 to 2000

This data reveals that the share of commuters who traveled 15 minutes or less to work has decreased region-wide from 1990 to 2000. In addition, the share of commuters that drove 45 minutes or more to work has increased over this same time period.

As mentioned above, the transportation network within the ASA corridor also provides for the movement of freight. Although separated by a distance of roughly 100 miles, the two metropolitan areas have distinct but complementary economies. Within the Austin metropolitan statistical area, economic activity is centered on State government, the University of Texas (which is one the largest universities in the U.S.), information technology and biotech/pharmaceutical companies (The Greater Austin Chamber of Commerce and City of Austin 2008). San Antonio’s economies are based on military services, processed food manufacturing, semi-conductor manufacturing, transportation, and logistics. Both cities also have strong tourism sectors (San Antonio Economic Development Foundation 2005). Over time, economic activity within the two metropolitan areas has become interlinked. A study of commodity flows between the

Austin and San Antonio metropolitan areas shows that intra-regional freight movement has increased overall with more tonnage traveling southbound and greater valued goods traveling northbound (US Census Bureau 2007). Table 6 provides the details of intra-regional commodity flows, for all modes of freight transportation, between the Austin and San Antonio metropolitan regions from 2002 and 2007.

Year	**Value in Millions $**	**Tons (000)**	**Ton-miles**
2002 – From Austin to San Antonio	$1,009	507	30
2007 – From Austin to San Antonio	$689	2,202	121
2002-2007 – Change in Southbound Commodity Flow	-31.7%	334.3%	303.3%
2002 – From San Antonio to Austin	2,731	3,258	625
2007 – From San Antonio to Austin	4,251	9,073	566
2002-2007 – Change in Northbound Commodity Flow	55.7%	178.5%	-9.4%
2002 – Overall	$3,740	3,765	655
2007 - Overall	$4,940	11,275	687
2002-2007 - Overall Change in Commodity Flow	32.1%	199.5%	4.9%

Source: (US Census Bureau 2007)

Table 6: Commodity Flows between Austin and San Antonio MSAs – 2002 and 2007

Freight truck through-movement on the I-35 has also dramatically increased. Texas is the primary U.S. state exporter and the I-35 corridor is highly influenced by its role in international trade. Nearly 80% of Mexico’s trade with US and Canada passes through Texas with 75% traveling by truck northbound on I-35 (ASAICRD 2003). Since the passage of NAFTA, loaded truck crossings at Laredo have gone from 60,000 - 66,000 trucks per month to 135,500 trucks per month and freight rail traffic in the corridor has more than doubled since the passage of NAFTA (ibid). According to the Bureau of Transportation Statistics, rail was the dominant transportation mode for freight movement between Mexico and the US through the Port of Laredo from 1995 and 2000 however statistics since 2000 shows that trucks have significantly surpassed rail as the preferred mode of freight movement along the corridor. In 2009, trucks moved almost 37 million pounds of freight, worth over just under $200 million, through the Port of Laredo. Current trends show the volume of freight trucks on the I-35 between Austin and San Antonio has grown at an annual rate of 15% (BTS 2010). The future of freight movement through Texas could significantly increase however. According to the *2009 National Rail Plan*, “the completion of the Panama Canal expansion project in 2014 could significantly alter US and international trade patterns and shift current freight flows to or from different port facilities with subsequent increases in traffic on corridors which are not accustomed to such intensive use.” (FRA 2009c). The Texas 2030 Commission report also acknowledges that freight flow may change significantly in the future. They report that the increase in commodity flow resulting from the North American Free Trade Agreement and the reconstruction of the Panama Canal, will produce a “future ‘tidal wave’ of freight on Texas highways” (2030 Commission 2009).

The recent growth trends have already put pressure on the current transportation infrastructure and the forecasted growth could add to the already strained capacity of the I-35 corridor as indicated by current levels of delay. In 2010, TxDOT conducted a study to designate the 100 most congested roadway segments in the state of Texas. The results of this study reveal that the I-35, between the Austin and San Antonio metropolitan area, experiences significant congestion. Table 7 highlights the data collected for the I-35 corridor.

Rank	I-35 From/To	Annual Hrs of Delay per Mile	Annual Hrs of Delay	Annual Cost of Delay
4	From SH 71 to US 183 (Austin)	421,778	3,880,359	$84.4 million
48	From Loop 353 to US 281 (San Antonio)	116,342	488,637	$10.63 million
49	From FM 1518 to Loop 1604 (San Antonio)	116,202	255,644	$5.56 million
62	From I 410 North to Loop 1604 (San Antonio)	102,203	899,163	$19.34 million

Source: (TxDOT 2010a)

Table 7: Congestion on the I-35 – 2010

While the above segments are in the urban areas of Austin and San Antonio, the challenges of congestion are also being experienced in the smaller communities along the corridor. Between 1993 and 2008, Buda, TX has seen a 150% increase in average annual daily traffic on I-35, New Braunfels, TX has seen a 100% increase and Round Rock, TX a 86% increase (TxDOT 1993). The cost of congestion is manifested with the inability to plan a timely trip and it affects everyone whether they are traveling to work, attempting to deliver just-in-time goods and services, or attempting to pass through.

LACK OF MODAL CHOICE CONTRIBUTES TO MOBILITY CHALLENGES

Mobility challenges manifest in two ways: increasing congestion and inadequacy of travel options. Both of these problems result in additional hours spent traveling, more fuel purchased, interference with work, loss of leisure time with family and friends and increased cost of goods. Travel options within the ASA corridor are limited which accentuates the congestion problem and cause challenges. In addition to the I-35, other north-south highway routes that connect the region include the US 281 corridor which is a partially-access controlled arterial that traverses the country from McAllen, TX at the US-Mexico border to the US-Canada border in Dunseith, ND. As it not access controlled between the Austin and San Antonio metropolitan area, speed limits are slower than the

I-35 and traffic flow can be interrupted by traffic entering the roadway from surrounding streets and land uses. The Central Texas Turnpike System is currently in the process of building the SH 130, a 65-mile toll road that parallels I-35 to the east. When complete, SH 130 will connect the I-35 in Georgetown to the I-10 east of Seguin. Segments 1 through 4 are currently open to traffic with major intersections at the I-35, US 79, SH 45 North, US 290, and SH 71. Segments 5 and 6 are schedule for completion in 2012 with intersections at US 183 and I-10 (Central Texas Turnpike Systems 2006). SH 130 has the potential to provide congestion relief for travelers wishing to pass through the region, however this corridor does not connect major employment centers as I-35 does and with increasing volatility of gas prices both freight companies and the traveling public have voiced concerns over toll roads in Central Texas. Organizations such as The San Antonio Toll Party and CASHTRAP (Citizens Against State Highway to Toll Road Abuse and Proliferation) are two such groups that are fighting against toll roads in Texas (San Antonio Toll Party 2011, CASHTRAP 2011).

In addition to roadways, there are a couple of transit options that serve the ASA corridor. Amtrak Texas Eagle service offers a passenger rail connection between San Antonio, San Marcos and Austin via shared track with Union Pacific. This line is a long distance route that travels from San Antonio, TX to Chicago, IL. The service is currently limited to one northbound and one southbound train each day. Any delays along the line mean that the Texas Eagle is subject to unreliable travel times. Between 2005 and 2009 the on-time performance (OTP) of the Texas Eagle ranged from 18 percent of trains arriving on time in 2008 to 75 percent in 2009 (Amtrak Government Affairs 2010). The combination of limited frequency and variable travel times makes this service a less desirable option for regular travelers with time-sensitive needs.

Founded in 1914, Greyhound Lines, Inc. (Greyhound) is the largest provider of intercity bus services in the United States with services to more than 2,300 destinations. In addition to its regularly scheduled bus services, Greyhound offers express and charter services. Between Austin and San Antonio, Greyhound offers between fifteen to seventeen daily trips in each direction, some of which are express service and some which make a connection in San Marcos (Greyhound 2010). The timeliness and convenience of this bus service however is tied to both the station locations and the route. The Greyhound station serving Austin is located north of the central business district with limited connecting transit options. And, Greyhound buses travel on the I-35 and their timeliness are subject to the traffic conditions on the roadway. The buses, in fact, become a contributing factor to the congestion on the interstate.

DIMINISHING AIR QUALITY

In addition to congestion and lack of modal choice, the ASA corridor is also experiencing diminished air quality. Carbon dioxide (CO2) represents 95 percent of the total greenhouse gas emissions of the transportation sector. For every gallon of gasoline burned 20 pounds of CO2 emissions are produced and ozone producing toxics such as nitrogen oxides and volatile organic compounds are released into the environment (Davis 2007). Between 1990 and 2004 greenhouse gas emissions in the US have increased 29 percent. According to a 2008 study by the Victoria Transport Policy Institute, pollution generated by motor vehicles results in $.01 to $.41 per vehicle mile traveled in external costs. Recovery of these costs are not reflected in the cost of a vehicle or in the price gas but are born by the community in terms of health expenses and costs to mitigation pollution and maintain regulatory compliance (VTPI 2009).

Under the *Clean Air Act of 1970*, the Environmental Protection Agency (EPA) sets national ambient air quality standards for several air pollutants to protect public health and the environment within an adequate margin of safety, including ozone. In the state of Texas, the Texas Commission on Environmental Quality is tasked with implementing these standards. In 2002, due to unhealthy levels of air quality, both Austin and San Antonio Metropolitan Statistical Areas (MSAs) were in violation of the federal 8-hour ozone air quality standard. So, in 2004 they developed *Early Action Compacts*, pledging to meet air quality standards by 2007 in return for the dismissal of penalties as a result of these violations. The Austin and San Antonio MSAs successfully improved the region's air quality and are currently in attainment of all air quality standards, however complying with air quality standards in the Austin-San Antonio corridor could become increasingly challenging (TCEQ 2010). The EPA has proposed more stringent standards for ozone emissions, which if implemented would put the region in violation again. The EPA is also petitioning for the regulation of carbon dioxide.

Railroads have been recognized as an efficient and more environmentally-friendly transportation option for both freight and passenger movement. According to the EPA, train locomotives contribute 2.6 percent of the total greenhouse gas emissions released from mobile transportation (EPA 2006). In a comparison of gallons of fuel consumed to haul one ton of freight across the US, trains are four times more fuel efficient that trucks. And, over the years, trains have improved fuel efficiency; between 1980 and 2008, the average fuel efficiency of locomotives has improved 95 percent (Association of American Railroad 2011). In terms of energy used per passenger mile, passenger trains are 20 percent more efficient than airplanes and 36 percent more efficient than cars. (Association of American Railroad 2010). As such, passenger rail is largely acknowledged as the preferred mode of transportation to improve air quality. According to a 2009 survey conducted to evaluate infrastructure needs and solutions in US cities, the preferred solution to address climate change is to foster sustainable mobility; in particular to improve the capacity and access to public transportation systems (The US Conference of Mayors 2009). Transportation agencies in the ASA region are also increasingly looking to passenger rail as a modal choice that could reduce the number of vehicles on the I-35 corridor, and thus congestion and improve air quality in the region.

PROPOSED PASSENGER RAIL SERVICES – AUSTIN-SAN ANTONIO CORRIDOR

According to the TxDOT *2010 Rail Plan* three passenger rail concepts are being explored within or including the ASA corridor. 1. Based on its previous successes with intercity corridors between 50 and 500 miles apart, Amtrak is exploring the ASA corridor for possible new intercity corridor services, 2. The Lone Star Rail District, a state agency created in 1997, was created to develop passenger rail services between the Austin and San Antonio metropolitan areas. They are currently working on the Lone Star Passenger Rail project which would offer new passenger rail service between Georgetown, Texas and San Antonio, Texas with 16 stations. 3. The Obama administration has expressed a desire to implement high-speed rail as a means to “ensure safe and efficient transportation choices, build a foundation for economic competitiveness, promote energy efficiency and environmental quality, and support interconnected livable communities” (FRA 2009c). The ASA corridor is a small segment of the designated South Central high-speed rail corridor that connects San Antonio to Austin and on to Dallas after which it forks north, terminating in Tulsa, OK and northeast, terminating in Little Rock, AR. Another high-speed rail alignment known as the Texas T-Bone has been proposed which connects San Antonio to Dallas via Austin and Waco, TX and Houston to Waco (Texas High-Speed Rail and Transportation Corporation 2002).

Amtrak – Intercity Corridor Services

While Amtrak is known for providing long-distance rail services throughout the United States, over the past decade they have expanded their business line to include intercity corridor services such as the Downeaster that connects Boston, MA to Portland, ME, the Heartland Flyer that connects Dallas/Ft. Worth, TX to Oklahoma City, OK, the Sounder that connects Eugene, OR to Vancouver, BC and others. According to a 2008 Amtrak presentation, corridor services account for 49 percent of all Amtrak ridership and they are responsible for 21 percent of total revenue and are growing. Based on the success of the intercity corridor services, Amtrak aims to increase intercity passenger rail ridership 50 percent by 2020 by developing new routes. Amtrak is using the Regional Planning Organization’s national map of megaregions as a tool to identify the location for future corridor services. The ASA corridor is one that is under consideration (McArthur 2008). Specific plans for ASA Amtrak service are still in the planning stages and are being coordinated by Amtrak and TxDOT.

Lone Star Rail District – Lone Star Passenger Rail Service

On May 13, 1997 enabling legislation was passed by the 75th Texas State Legislature, as codified in *Vernon’s Texas Civil Statutes, Chapter 13, Title 112, Article 6550c-1*, which authorized the formation of intermunicipal rail districts. Pursuant to the bill, intermunicipal rail districts may form for the purposes of creating a regional passenger rail system between two municipalities, each with a population of more than

450,000 and which are located not farther than 100 miles apart. These districts are granted the power of eminent domain, and they may issue revenue bonds, and acquire, construct, develop, own, operate, and maintain passenger rail facilities. The Lone Star Rail District (formerly the Austin – San Antonio Intermunicipal Commuter Rail District) was created to specifically address the passenger rail service needs between Austin and San Antonio (TxDOT 2010b). Based on over ten years of technical studies and support from the Texas Legislature, TxDOT, Union Pacific Railroad, Amtrak, and both Austin and San Antonio metropolitan planning organizations, the Lone Star Rail District is proposing new intercity passenger rail service between the Austin and San Antonio metropolitan areas. A locally preferred alternative (LPA) was adopted in 2005, which defines the ASA intercity passenger rail corridor from Georgetown, TX (north of Austin) to San Antonio, TX with 15 stations in between. The LPA proposes using the existing Union Pacific Railroad corridor between Round Rock and San Antonio and would also involve approximately seven miles of new track between Round Rock and Georgetown, and five miles of new track from downtown San Antonio to the City South development, for a total project length of 117 miles. As of 2011, the Lone Star Passenger Rail project is conducting environmental studies and engineering analysis (Lone Star Rail District 2011).

High-Speed Rail Corridor

In 1989 the Texas State Legislature created the Texas High Speed Rail Authority (THSRA) which was tasked with determining if high-speed rail is feasible in the state of Texas and to select a firm to design, build and operate high-speed rail service in Texas. The initial investigations studied the potential of the high-speed rail within the Texas Triangle. 1991 ridership projections revealed that high-speed rail in the Texas Triangle could generate 11.9 million riders (TxDOT 2009b). This early high-speed rail effort failed however when investors pulled out of the project; the THSRA was formally dismantled in 1995 (ibid).

More recently, President Obama signed the *American Reinvestment and Recovery of 2009* which designated $8 billion specifically for the development of high-speed intercity rail service in the United States. In order to be eligible for federal funding however the States had to apply for high-speed rail corridor designation. Approved applications for funding must show that the corridor has the potential to achieve 90 miles per hour and be able to address safety concerns at highway-railroad grade crossings (FRA 2009d). While listed in the *2010 Texas Rail Plan* as a proposed passenger rail project, the plan also notes that Texas has won limited federal funding to make the capital improvements and safety enhancement needed to achieve true high-speed rail in Texas (TxDOT 2010b).

Each of the proposed passenger rail projects identified in the *2010 Texas Rail Plan* are at different stages of development. All of them however are exploring to feasibility of using the existing rail in the ASA corridor, which is currently owned and operated by Union Pacific.

WHY IS TRACK-SHARING WITH FREIGHT RAILROADS THE PREFERRED SOLUTION?

Passenger rail is often favored as a means to address transportation congestion without requiring the construction of additional highway capacity, and as a cost efficient mode of moving passengers as it requires lower operating costs per passenger mile than highway travel (Prozzi 2006). A 2006 study, analyzing passenger-freight track sharing in the state of Texas, revealed public agencies perceive track sharing as a cost effective means to offer passenger rail service within a constrained budget (ibid).

The introduction of TxDOT's *Strategic Plan 2009 through 2013* acknowledges, that "every transportation agency in Texas is experiencing huge increases in the cost of doing business," and that "cost inflation has significantly increased the amount of capital required for transportation projects" (TxDOT 2008). *The Highway Cost Index* (HCI) maintained by TxDOT, is a tool to help predict construction costs for proposed transportation projects including costs for earthwork, base work, structural work, and surfacing. According to the HCI 2011 update, which is indexed based on costs in 1997, the twelve month moving average cost for highway construction overall has increased approximately 95 percent from December 1998 to December 2008. More recently, and largely attributable to overall economic conditions in the US, this index has dropped from its all time high in 2008 but in January 2011 the HCI was still double the 1998 index (TxDOT 2011). Given these conditions, TxDOT and other transportation agencies are seeking cost-effective solutions to meet the future transportation needs of the state.

Texas is not alone in its challenge to finance transportation improvements. According to a survey conducted for the United States Conference of Mayors in April 2009, the most pressing challenge facing cities today is funding infrastructure improvements. In light of the economic conditions in 2009, a large majority of cities surveyed are expecting to be operating with reduced budgets to address infrastructure needs in the coming years. This survey reveals that US cities are focusing their limited resources on the most immediate challenges; improving their existing and aging roadway and storm and wastewater systems, which have deteriorated as a result of years of deferred maintenance. In discussing how federal stimulus funding should be targeted in the future, most cities surveyed emphasize transportation needs. Most cities, particularly large cities of 100,000 or more residents, would like to expand the capacity of their public transportation systems while maintaining, but not expanding, their existing roadway systems (The US Conference of Mayors 2009).

Many states and metropolitan areas, including the Austin-San Antonio corridor, are feeling the burden of insufficient transportation infrastructure to meet the growing demands. Not only is a shared track scenario perceived as prudent from a financial perspective but, it is also seen as a means to relieve congestion in a timelier manner with less political controversy. Planning a new rail corridor could result in a lengthy and potentially controversial process of acquiring land for right-of-way. A recent project in Texas, the Trans-Texas Corridor 35 (TTC-35) experienced such a challenge. “The demise of the project began when public hearings were held throughout the state. Thousands of citizens voiced their opposition to the TTC-35 citing the fact that too much private property would be taken for the project” (Hall 2010). With a shared track scenario, a rail corridor is already established and infrastructure is already in place. A shared track scenario however, does not come without its challenges. For one thing, freight railroads and passenger rail service have different needs, and many factors are involved in negotiating a track sharing scenario with a private railroad, including safety.

Chapter 2: Safety on Corridors Shared by Passenger and Freight Railroads and at Highway-Railroad Crossings

UNDERSTANDING FREIGHT AND PASSENGER RAIL NEEDS

Given the economic constraints of transportation funding from the public sector perspective, and the rising construction and right-of-way costs that go along with building highways, a shared track scenario is largely seen as a cost effective means to offer travel choices. In order for a track sharing scenario to be successful however, the needs of both freight and passenger operations must be understood. As expressed in the *2009 National Rail Plan*, both passenger service and freight railroads have vastly different need yet, stand to benefit under a shared track scenario as they are amendable to economies of scale (FRA 2009c).

The success of passenger rail largely relies on the performance of the system. Passenger train riders depend on reliable, on-time service that is safe and that offers a travel frequency that allows them to access their destinations at an appropriate and convenient time. “Passengers switch to rail when the combination of the positive attributes; safety, speed, reliability, comfort and convenience, outweigh the cost of transportation alternatives.” (FRA 2009c) As profit-making private corporations, freight railroads want the most profitable use of the right of way and track that they own. They are successful when costs are kept low, and they can provide their customers with reliable and convenient service. Slow and/or undependable service, particularly with high-value freight or just-in-time deliveries, can result in loss of market share. (FRA 2009c, Prozzi 2006). As each service type has their specific needs to be successful, the *National Rail Plan* recommends that the total benefits of a joint freight-passenger rail improvement project be the metric by which the project is evaluated and discourages viewing the freight and passenger modes independently (FRA 2009c). This suggests that public agencies wishing to pursue passenger rail as a shared track project, must establish and maintain working relationships with the freight railroad in order to plan for the needs of the corridor and to negotiate terms and responsibilities.

As part of the development of the *National Rail Plan* and in furtherance of the discussion of high-speed rail in U.S., as called for in the Reinvestment and Recovery Act of 2009, the FRA conducted outreach efforts with public and private transportation stakeholders. Meetings were held in Charlotte, NC, Orlando, FL, Seattle, WA, Sacramento, CA, Houston, TX, Chicago, IL, and Philadelphia, PA. Of the top ten issues discussed, collaboration and stakeholder agreements was the most critical element to successfully implementing the high-speed rail vision for the US. (FRA 2009c). A review of the literature reveals that safety of the corridor is an important topic of discussion when negotiating a track sharing agreement.

SAFETY AS ONE KEY NEGOTIATION FACTOR FOR SHARED USE SCENARIOS

In order for states to apply for federal grants for intercity or high-speed rail projects, written agreements must already be worked out with host freight railroads regarding safety and other issues such as infrastructure capacity, compensation and liability (AAR 2011). Compared to other modes of transportation, railroads provide the safest way to move both freight and people (AAR 2011). However, maintaining safety while growing both passenger and freight rail services within a shared corridor requires careful consideration. From the perspective of the Association of American Railroads (AAR), an organization that represents freight railroads, passenger trains that travel at lower speeds may be able to safely share track or right of way with freight trains under the right conditions but higher speed trains should operate on separate track and high-speed passenger rail service should be run in sealed corridors, without highway-railroad at-grade crossings. In all cases however, “safety concerns must be paramount” (AAR 2011). Jolanda Prozzi conducted research with the University of Texas at Austin Center for Transportation Research to help identify the key factors that lead to successful negotiations between freight railroads and public agencies wishing to share track for proposed passenger rail service. One of the four key factors she discusses is safety of the corridor. Her findings conclude that “in many instances, safety concerns drive decisions about shared operations” and safety at highway-railroad crossings become more of a concern when increased rail traffic and speeds would result from a track sharing scenario (Prozzi 2006).

These sentiments are mirrored by freight railroads themselves. CSX has established four principles that must be taken into consideration when adding passenger rail service to one of their lines; among them safety is a priority (Atkinson 2010). Equally, Union Pacific’s *Commuter Access Principles* emphasizes that “safety must come first” with a preferences for separate freight and passenger operations. When contemplating a shared track scenario, Union Pacific expects that public agencies fund safety improvements, including improvements to highway-railroad at-grade crossings (Union Pacific 2009). The Burlington Northern Santa Fe’s (BNSF) *Commuter Principles* also pays specific attention to highway-railroad crossings; as a requirement for a shared use agreement with BNSF, improvements must be made to grade crossing warning systems and grade separations built at high-risk crossings as a means to minimize the risk of accidents. Concerns about accidents at highway-railroad crossings are twofold; first accidents may cause service interruption, and secondly accidents at highway-railroad crossings pose a significant liability risk under current regulations (BNSF 2007).

HIGHWAY-RAILROAD AT-GRADE CROSSINGS – UNIQUE LIABILITY RISK

The *Amtrak Reform and Accountability Act of 1997* was passed to address liability issues related to passenger train accidents on share corridors. It establishes an aggregate award cap of $200 million to all rail passengers for all claims, including punitive damages, relating to a single accident. This legislation covers all passenger claims against Amtrak, high-speed railroads, commuter rail authorities, freight railroads, excursion trains, States, and their employees and operators. As currently written, the cap in this legislation only covers claims brought by train passengers; the cap does not apply to non-passenger claims, such as those made by highway users involved in highway-railroad crossings accidents (Sheys 2008). In addition, the courts have not held up this cap in cases of gross negligence. Because of this freight railroads pay particular attention to the safety risks at highway-railroad at-grade crossings; a serious accident at a crossing could “conceivably threaten the financial health of a large Class I railroad” (Prozzi 2006). During negotiations with public agencies freight railroads are likely to require full faith and credit indemnification.

Based on the unique liability risks associated with highway-railroad crossings, consensus among freight railroads that safety is top priority, and the eligibility requirements tied to federal funding of passenger rail projects, public agencies proposing a shared track scenario must conduct a risk assessment of the highway-railroad crossings that exist along the corridor that they propose to use. In light of Texas’ status as the top state in the nation for accidents at highway-railroad crossings, as discussed in Chapter 1, evaluation of risk at highway-railroad crossings along the ASA corridor is a must.

THE FRA AND EVALUATION OF RISK AT HIGHWAY-RAILROAD CROSSINGS

The growth of the railroad mode of transportation began in the US in the 1830s and was a significant contributor to the westward expansion of the country. Supported by the federal government and some states via land grants and loans, the network of railroad grew and towns and cities began establishing along the lines. At the time of expansion, railroads were allowed to build their track across existing streets, at grade, as a means to save on the cost and time associated with building grade separations. When the railroads were initially built highway-railroad grade crossing were not problematic, as the number of trains traveling through was small and the speed of the trains was slow. In addition street traffic was slow moving and largely by foot or horse-drawn vehicles. Growth of the west collided with the advent of the automobile however and changed how communities viewed at grade highway-railroad crossings. By the early 1920s the automobile started becoming a household item and new communities were being designed in a grid pattern of streets to accommodate for them. This grid pattern however did not always work well with the existing rail, whose lines were layout based on natural features and topography. In building the grid pattern, a crossing was generally provided at each road; in some communities there were 10 at grade crossings per mile. Thus began the conflict between highway and railroad users at grade crossings. Over the course of decades, legislative mandates, financing tools, and design standards have been put in place to improve safety at these crossings. One critical tool in evaluating the challenges, risks, and safety needs of highway-railroad crossing was the quantification of incidents (FRA 2007)

The passage of the *Accidents Reports Act of 1910* was the first legislation enacted to quantify the highway-railroad conflicts by requiring rail carriers to report all collisions that resulted in death, incapacitating injury or more than $750 in damages to railroad equipment, track or the roadway to the federal government. In 1975 these reporting standards changes to include all impacts between on-track rail equipment and all highway users, including all motorized vehicles as well as pedestrians, bicycles and other users. The U.S. Department of Transportation's *National Highway-Rail Crossing Inventory* (Crossing Inventory) was developed in the early 1970s through the cooperative efforts of the Federal Highway Administration (FHWA), the Federal Railroad Administration (FRA), the Association of American Railroads (AAR), as well as individual states and railroads. One of the first tasks in creating an inventory was to develop a coding system to identify each crossing in the nation. With a unique identification for each crossing, the inventory linked information about the physical and operational characteristics of the rail and roadway at the crossing to the accident report data (ibid).

Today the Federal Railroad Administration's Office of Safety Analysis is responsible for maintaining these public databases. The states however are responsible for updating the inventory. State have an incentive to maintain the inventory as is helps state DOTs meet the requirements of *Federal-Aid Guide Title 23 – Code of Federal Regulations*, which calls for the states to develop and implement highway safety improvement programs. In addition to maintaining the highway-railroad crossing inventory, the FRA also maintains the *National Railroad Accident/Incident Reporting System* which tracks all accidents/incidents (ibid). Title 49 of the Code of Federal Regulations requires that railroads report all "impact between railroad on-track equipment and an automobile, bus, truck, motorcycle, bicycle, farm vehicle, or pedestrian at a rail-highway grade crossing" (CFR 49). Both datasets share the use of the unique crossing identification number and together form a dataset that can be used to evaluate safety at the crossings.

HAZARD INDICES AND ACCIDENT PREDICTION AND A NEED FOR A NEW APPROACH

General guidelines appear in the FRA's *Railroad-Highway Grade Crossing Handbook* for conducting a hazard assessment of highway-railroad crossings. The New Hampshire Hazard Index is a general formula that multiplies the annual average daily traffic (AADT) by the average daily train traffic by a protection factor which ranks warning devices. This index however is not universally used by all states and variations to the formula making it difficult to use these hazard indices for comparatively purposes on the national scale (FRA 2007). In its Action Plan, FRA has recognized that this approach to hazard assessment produces a bias result towards "urban areas and main roads where traffic densities are high" As such, many low density crossings are ranked lower yet may be those "that would benefit most from low cost improvements" (FRA 2011).

In addition, the FRA administers the Web Accident Prediction System (WBAPS) which correlates physical and operational factors with a five-year crash history and results in an accident prediction value which represents the probability that a collision between a train and a highway user will occur at the crossing in a year. This tool is intended to help agencies identify "where to focus attention for improving safety at public highway-railroad intersections" (FRA 2010b). While producing a predicted accident probability, this information does not call out which of the physical or operational factors is most related to the incidence of an accident. As such, indentifying how improvements in safety can be made cannot be ascertained from these predictions. The FRA Action Plan also mentions the need for a new approach to accident prediction; they call for rebuilding the computer model and updating the imbedded accident prediction formula (FRA 2011).

The following chapter describes a possible approach for correlating the physical and operational characteristics of highway-railroad crossings with a five-year accident history (in this case 2005 to 2009) that results in the identification of relationships between the characteristics themselves and the five-year history of accidents. Instead of looking at one crossing in isolation, this approach calls for a national analysis of highway-railroad crossings to determine which physical and operational characteristics have a stronger relationship to accidents. This learning will then be applied to the ASA corridor.

Chapter 3: Crossing Inventory and Accident History Analysis – Shared Highway-Railroad Crossings in the Nation and the Austin-San Antonio Corridor

PROPOSED ANALYSIS

If any of the proposed passenger rail projects within the ASA corridor, as described in Chapter 1, are to proceed with their plans to share track with Union Pacific Railroad, one of the items of negotiation with the railroad will be about the safety at highway-railroad at-grade crossings. As mentioned in Chapter 2, the FRA databases and accident prediction output are a starting point for analysis however further investigation is recommended. Specifically, the data and analysis that is currently available from the FRA does not describe how the physical and operational characteristics of highway-railroad crossings are related to accidents. This analysis will attempt to identification these relationships by first looking at national statistics to answer the question:

> *Which operational or physical characteristic of highway-railroad crossings, that are currently being used by both freight and passenger rail in the US, have a relationship with the total number of accidents that occurred between 2005 and 2009?*

The findings from the national analysis will then be applied to the crossings along the ASA corridor to identify potential concerns.

METHODOLOGY AND ASSUMPTIONS

As this report will analyze each physical and operational characteristic for their relationship to the total number of accidents at highway-railroad crossings between 2005 and 2009, a regression analysis will be conducted with the dataset. Regression analysis is a commonly used method of measuring the correlation between two or more phenomena and is the “statistical tool appearing in legions of scientific papers” This method was chosen as it is used to “establish connections that call for closer investigation.” While the linear regression tool helps determine relationships it cannot be used to determine causation (Dizikes 2010). A data analysis and statistical software called STATA v. 8.2 was used to perform regression analysis (StataCorp).

The physical and operational characteristics within the database are binary in nature, and are referred to as categorical predictors or dummy variables. For example a highway-railroad crossing that is protected by a stop sign is assigned a one representing “yes” in the stop sign column and a zero, representing “no” in the columns for the other warning device types that are not a stop sign. Interpreting the results of a regression model is different with categorical predictors than with variables that are continuous, or have a range of values. Using the stop sign example, the coefficient for stop sign equals the difference between the predicted mean number of accidents in five years if a stop sign is present (“yes”), minus the predicted mean number of accidents in a five-year period if a stop sign is not present (“no”). The constant, or the y intercept becomes the predicted mean number of accidents in a five-year period if no stop sign is present (“no”). With continuous variables the coefficient is equal to the difference in the mean independent variable for every one increase in the dependent variable and the constant is the predicted y-intercept (Bruin 2006).

Generally an assumption is made when using linear regression that the model produces a slope and y-intercept that is the best fit. This assumption is tested by conducting a T-test; the P-value associated with the coefficient tests the statistical significance of the independent variable or the probability that the coefficient that corresponds to the independent variable could be a result of random chance. The results of the regression with categorical variables, however, already produce the T-test without additional data processing. This is also true for conducting an anova analysis. The anova analysis tests the probability of F (P-Value) where F equals the mean square of the model divided by the mean square of the residual (ibid). A threshold of 0.05 for both the T-test and P-value was used to answer the question of whether the independent variable reliable predicts the dependent variable at a 95 percent confidence level.

Level 1 Screening

The purpose of level 1 screening is to test the influence that “yes” for each variable has on the five-year accident history. Again, using the stop sign example, if the coefficient for stop sign is a greater than zero, then the presence of the stop sign (“yes”) has a higher predicted mean than no stop sign (“no”) and therefore can be said to have a stronger relationship to accidents than no stop sign. If the coefficient number is less than zero then that means the predicted mean for “yes” was smaller than the predicted mean of “no”, therefore no stop sign has a stronger relationship to the five-year accident history. Results that predict “no” to have a stronger relationship are less useful for this analysis because “no” may represents more than one possible alternative. For example, if a crossing does not have a stop sign it could have bells or it could have gates or it could have no signage at all. Those variables, as evaluated individually, which resulted in a coefficient greater than zero and met the 0.05 threshold for the T-test and the P-Value, were passed along for level 2 screening.

Level 2 Screening

Using STATA, paired sets of variables were created to represent the presence of two characteristics; for example, “yes” stop signs and “yes” public crossing. Using this example, the regression is run with the “stop sign and public” variable. In this regression the constant is equal to the predicted mean of not having either stop sign or public characteristics and the coefficient for “stop sign and public” represents the difference between “yes and yes” and “no and no”. Again, if the number is greater than zero the paired variables have stronger relationship with the five-year accident history than without either variable. These paired regressions were screened using the 0.05 threshold for the T-test and the P-Value. The remaining pairs were put into a matrix. Each variable pair was compared leaving one of the variables as a constant and then the coefficients from the regression were ranked from highest to lowest for each constant. The constants with the most pairings that yielded coefficients greater than zero and were determined to be statistically significant if the met the 0.05 threshold and were then grouped and the top ten were moved forward for further analysis. The pairing of the top ten constants were then looked at for the variables, that when paired, create the most change (the greater difference from zero). The projected mean of these pairings were compared with the projected means of the variables as individually analyzed. All pairings resulted in an increase in the projected mean and are discussed in the Results of Data Analysis section of this paper.

Level 3 Screening

The final round of analysis uses multiple regression to identify characteristics, as grouped, that have an impact of highway-railroad crossings with a focus on train speed and train volume. The addition of a passenger rail component to the ASA corridor would add to both the daily volume of trains as well as the speed of the trains. The proposed Lone Star Passenger Rail service proposes train speeds of about 75 miles per hour and proposes to add 24 daily trains to the corridor (Lone Star Rail District 2011). The other two passenger proposals are still in the planning phase and have not yet formulated a service schedule. According the FRA's High-Speed Rail Strategic Plan, emerging high speed rail corridors are anticipated to travel at 90 to 110 miles per hour and conventional intercity rail services travel generally travel between 79 and 90 miles per hour (FRA 2009d). Based on this information, Level 3 Screening focuses on crossings that experience trains speeds between 80 and 89 miles per hour and train volumes between 46 and 60 daily trains within the national dataset to help identify crossings along the ASA corridor that could be impacted by the implementation of passenger rail services, and the effect on accidents at these crossings.

About the Dataset

The data obtained by the FRA for the crossing inventory database and accident/incident files are submitted via a form and are subject to keypunch and submission errors. While FRA has a procedure for correcting errors as they are found, there is still a possibility that some errors exist. In addition, updates to the records, as submitted by the States and railroads, are only mandatory when an incident occurs or the crossing warning device is changed. The FRA receives approximately 100,000 inventory file changes and updates that are voluntarily submitted each year however, data records for all crossings may not be completely current. Erroneous, inaccurate and non-current data can alter the results of this analysis (FRA 2010b). Average annual daily traffic (AADT) is one characteristic within the crossing inventory database that was consistently found to be out of date with information reporting back to 1978. As such, this variable was not analyzed in this report. The omission of AADT has the potential to influence the model results by creating a biasing the results of the remaining variables considered. In addition, any crossings with an incomplete inventory were removed from consideration. The crossing inventory and accident history data for this analysis was gathered in November 2010.

Variables Considered

The following characteristics were analyzed to determine if their presence is correlated to the number of accidents between trains and roadway users that occurred at shared highway-railroad crossings between 2005 and 2009.

Variable	**Description**
Location of Crossing In City	This physical characteristic describes whether the highway-railroad crossing located within the city limits of an incorporated city or in between cities.
Type of Crossing Public	Public crossings are “those on highways under the jurisdiction of, and maintained by, a public authority and open to the traveling public” (FHWA 1986)
Type of Crossing Private	Private crossings are “those on roadways privately owned and generally only utilized by the land owner or licensee” (ibid)
Type of Crossing Pedestrian	Pedestrian crossings are “those that are used solely by pedestrians” (ibid)
Train Operations Maximum Train Speed at Crossing	The maximum train speed at a crossing is determined by the class of track at the crossing. Track class 1 has a 10 miles per hour speed limit for freight trains and 15 miles per hour for passenger trains and track class 9 allows for speeds up to 200 miles per hour. (FRA 2007). Speed was analyzed in groups of ten from 0 to 109 and then 110+ miles per hour.
Passive Warning Device No Sign or Signal	Crossings with no warning devices may be marked with the crossing number but with no other indication to a driver that they are approaching a crossing.

Table 8: Physical and Operational Characteristics of Highway-Railroad Crossings Analyzed

Variable	**Description**
Passive Warning Device Crossbucks	A minimum of one crossbuck must be used at every public highway-railroad crossing, alone or in combination with other traffic control devices. This variable will look at crossings that have crossbucks as their only warning device (ibid).
Passive Warning Device Stop Signs	Crossbucks are the regulatory sign that warns a highway user that they must yield to trains and stop if needed however, they are not well understood by the traveling public; stop signs are more recognizable. This variable will look at crossings that have stop signs (ibid).
Passive Warning Device Other Sign or Signal	Other signs or signals include those that are located in advance of the crossing and which serve to warning the highway user that a crossing is ahead. This variable will look at crossing that use additional signage or signals in advance of the crossing (ibid).
Active Warning Device Highway Traffic Signals, Wigwags, Bells, or Other Activated Device	Active warning devices are those that are activated by the approaching train via a detection circuit in the track. This variable looks at the following train activated warning devices; wigwags, bells, highway traffic signals, and other activated devices (ibid).
Active Warning Device Special Active Warning Device	Special active warning devices are those that are designed specifically to function with a surrounding condition such as approaches to ports or industrial facilities (ibid).
Active Warning Device Flashing Lights	Flashing lights are considered the more modern version of the wigwag and flash on and off between 45 to 65 times per minute. They can be mounted to a pole or on a cantilever where visibility is limited (ibid).
Active Warning Device All Other Gates	Of the active warning devices, gates offer a high degree of protection and are commonly used at crossings with high levels of street traffic. Gates provide a physical barrier intended to prevent highway users from entering the crossing when a train is approaching (ibid).
Active Warning Device Four Quad Full Barrier Gates	Of the warning devices used today, four quad full barrier gates provide the most security. Four gates are activated upon arrival of a train, blocking all directions of highway traffic. In addition the full barriers, or medians, prevent drivers from attempting to drive around the gates (ibid).
Surrounding Land Use Open Space	Open space may include areas that are forest – natural areas dominated by tree coverage that are generally over 20 feet tall; ranged – upland areas where grasses or shrubs represent the dominant cover type; or barren – areas of eroded soils or permanently exposed soil or rock outcrops with limited vegetation (Anderson et al. 1976).

Table 8, cont.

Variable	**Description**
Surrounding Land Use Recreational	Land where elements of the natural landscape, such as vegetation or topography, or use of a natural resource, such as water, is an integral part of recreational activities or settings (ibid.)
Surrounding Land Use Farm	Land used for raising livestock or under cultivation for food production purposes. Farms may also include land used for the growth of fibers, such as cotton or trees used for paper products. It can include lands termed agriculture, pasture, cropland, ranch, nurseries, and confined feeding operations (ibid).
Surrounding Land Use Residential	Single-family, multi-family, residential hotels, mobile home parks and other lands whose primary use is for lodging (ibid).
Surrounding Land Use Commercial	Areas predominantly used for the sale of products and services but may also include mixed land uses (ibid).
Surrounding Land Use Industrial	Facilities whose primary business varies from light manufacturing, such as design, assembly, finishing, processing and packaging, to heavy manufacturing which could include mining, raw materials mills, electric power generation plants, oil and gas facilities (ibid).
Surrounding Land Use Institutional	Structures of complexes that provide governmental, cultural and health services. Institutional land uses may also include educational, correctional, and military facilities (ibid).
Crossing Characteristic Perpendicular Highway 75 Feet or Less from Crossing	This characteristic determines if there is a perpendicular highway located less than 75 feet away from the crossing. This means that a vehicle crossing the track will encounter a roadway intersection less than 75 feet from the crossing.
Crossing Characteristic Smallest Angle at Which Roadway Crosses Rail 60 to 90 Degrees	The angle at which the highway and railroad cross has an effect on the visibility within the crossing in both directions. A crossing that is perpendicular, or 90 degrees, offers the highest visibility in both directions.
Crossing Characteristic Smallest Angle at Which Roadway Crosses Rail 30 to 59 Degrees	When the smallest angle of the crossing is reduced, in this case between 30 and 59 degrees, visibility in one direction (the opposite side of the smallest angle) is reduced.
Crossing Characteristic Smallest Angle at Which Roadway Crosses Rail 0 to 29 Degrees	As with the above, a crossing with the smallest angle between 0 and 29 degrees offers the least visibility in one direction.
Highway Characteristic Number of Traffic Lanes	This characteristic describes the number of traffic lanes crossing the track. For this analysis they were grouped: 1 to 2 traffic lanes, 2 to 4 traffic lanes, 5 to 6 traffic lanes, and 7 or more traffic lanes (ibid).

Table 8, cont.

Variable	**Description**
Highway Functional Class Urban Interstate	“Interstate highways are part of the national system of limited access highways that connect the nation's principal metropolitan areas and industrial centers. The Interstate System is divided into urban and rural sections. The distinction between urban and rural areas is based on population density figures from the US Census Bureau and adjusted by state and local government to reflect planning and other issues” Urban Interstate includes all roads on the Interstate System that pass through urban areas (FHWA 1989).
Highway Functional Class Rural Interstate	Rural Interstate includes all roads on the Interstate System that pass through rural areas (ibid).
Highway Functional Class Urban Other Principal Arterial	The average vehicle miles traveled miles on Principle Arterials ranges between 30 and 55 and generally account for 2 to 4 percent of the miles on the roadway network. Urban Other Principal Arterials serve major activity centers within a metropolitan area. They carry high volumes of traffic and offer the longest trip lengths. They are a route for entering and leaving urban areas, and provide a bypass around urban cores for the majority of through traffic. They connect central business districts with surrounding residential areas, major inner city communities or between major suburban centers (ibid).
Highway Functional Class Rural Other Principal Arterial	They provide for a substantial amount of statewide or interstate travel that are high density and provide for long distance travel (ibid).
Highway Functional Class Urban Minor Arterial	Minor Arterials offer a lower level of mobility and place more emphasis on access to surrounding land uses than Principal Arterials; however they are designed to provide for relatively high overall travel speeds, with minimum interference to-through movement. They carry local bus routes and provide intra-community connectivity in urban areas (ibid).
Highway Functional Class Rural Minor Arterial	Rural Minor Arterials link cities and larger towns, as well as to major resort areas that attract high travel volumes. It is a network that serves interstate and inter-county travel (ibid).
Highway Functional Class Urban Other Freeway or Expressway	An urban arterial that connects Rural Principal Arterials with Rural Minor Arterials (ibid).
Highway Functional Class Urban Collector	Urban Collectors provides the circulation within residential neighborhoods and commercial and industrial areas and collects traffic from local streets in residential neighborhoods and channels it into the arterial system. Unlike arterials, collector system may penetrate residential neighborhoods (ibid).

Table 8, cont.

Variable	**Description**
Highway Functional Class Rural Major Collector	The average vehicle miles traveled on Collectors ranges between 20 and 35 miles and they account for 20 to 25 percent of the miles on the roadway network. Rural Major Connectors link all county seats not on an arterial route, to larger towns, other traffic generators of intra-county importance, such as consolidated schools, shipping origins/destinations, county parks, and important mining and agricultural areas (ibid).
Highway Functional Class Rural Minor Collector	Rural Minor Collectors collect traffic from local roads and connect all developed areas to an Urban or Rural Major Collector. They also link the locally important traffic generators with surrounding rural areas (ibid).
Highway Functional Class Urban Local	The average vehicle miles traveled on Local roads ranges between 5 and 20 miles and generally account for 65 to 75 percent of the miles on the roadway network. Urban Local roads provide direct access to adjacent land uses and connect to the higher systems. They offer the lowest level of mobility and are not intended to serve through movement (ibid).
Highway Functional Class Rural Local	Rural Local roads constitute the rural mileage not classified as part of a higher system (ibid).
Highway Characteristic Posted Roadway Speed Limit	Roadway speed limits are generally designated based on the functional class of the roadway but can vary based on surrounding land uses, state and local laws, and planning issues. Roadways that do not have a posted speed limit, such as a driveway leaving an industrial park, are assigned a 5 miles per hour speed limit.
Local Regulation Whistle Ban	In 2005 the FRA enacted a rule that all trains must sound their horns between 15 – 20 seconds in advance of all public at-grade crossings, and at least ¼ miles in advance if a train in traveling faster than 45 miles per hour. As part of this rule, local governments may coordinate with railroads to establish quiet zones. Quiet zones must be at least ½ mile and have public crossings that are protected at a minimum by flashing lights and train activated gates (FRA 2006).
Rail Operations Total Number of Trains that Use the Crossing on an Average Day	Some of the rail corridors that share track with freight and passenger trains experience a train volume of over 150 daily train movements. They are broken up into groups of 15 from 0 to 150 and then greater than 150.

Table 8, cont.

OVERVIEW OF THE NATIONAL DATABASE

A preliminary review of highway-railroad crossings throughout the United States reveals that there are 410,934 in the United States as of 2009, of which 4.7% or 16,809 are shared by both freight and passenger trains. The sample used for this analysis was reduced to 10,270 shared highway-railroad crossings. Crossings were removed if the inventory information was incomplete, many of which were private crossings. As aggregated, the national accident rate at highway-rail crossings was 3.0 accidents per 100 crossings while shared highway-rail crossings were 9.7 accidents per 100 crossings (FRA 2010a, FRA 2010d).

OVERVIEW OF THE AUSTIN-SAN ANTONIO CORRIDOR

The highway-railroad crossings along the ASA corridor are define as those in Bexar, Comal, Hays, Travis and Williamson counties that are currently being used by Amtrak service. There are 233 at-grade crossings of which 115 had complete information for each variable. The crossings with missing information are all private crossings. In the state of Texas, private property owners are not required to report their crossing characteristics to TxDOT and therefore these are incomplete entries in the FRA inventory (FRA 2009b). The implications of missing data from private crossings will be discussed later in paper. In the five-year period between 2005 and 2009 the ASA corridor experienced 17 accidents and the table below provides a summary of the characteristics at crossings where at least five accidents have occurred in the past.

Variable	**Number of Crossings**	**Number of Accidents (2005 to 2009)**
Public	111	16
Smallest Crossing Angle between 60 and 90 degrees	108	16
All Other Gates	108	15
1 to 2 Traffic Lanes	95	14
In City Limits	84	12
16 to 30 Daily Trains	87	11
Highway Speed 26 to 35 miles per hour	64	8
Highway Speed 36 to 45 mph	43	8
Train Speed 70 to 79 mph	44	7
Residential	41	6
Train Speed 30 to 39 mph	40	6
Urban Minor Arterial	25	6
Open Space	32	5
Commercial	28	5

Table 9: Summary of Accident History on the ASA Corridor

LEVEL 1 SCREENING RESULTS:

The first review of the correlation analysis results considered whether the presence (“yes”) of each characteristic, evaluated individually, contributed positively to the number of accidents. Those variables where non-presence (“no) of a characteristic yielded a stronger relationship to the accidents were discarded.

Of the remaining variables, each regression model was reviewed for its statistical significance by looking at the results of the T-test and P-Value. Those variables that resulted in a T-test or P-Values greater than 0.05 were removed. What remains are physical and operational characteristics, whose presence has a relationship to the five-year accidents and whose coefficients are statistically significant. Table 9 shows the individual variables that passed through the first level of screening. See Appendix A for a summary of all variables considered and the regression model results for Level 1 Screening.

Variable	Coefficient	T-test	Variable	Coefficient	T-Test
Public Xing	0.1110	0.0000	In City	0.0709	0.0000
Hwy Less than 75'	0.0401	0.0000	All Other Gates	0.0823	0.0000
Urban Collector	0.1112	0.0000	Commercial	0.0967	0.0000
Hwy Speed 26-35 mph	0.0855	0.0000	Illumination	0.1081	0.0000
Urban Minor Arterial	0.1421	0.0000	46 to 60 Daily Trains	0.1120	0.0000
61 to 75 Daily Trains	0.1350	0.0000	3 to 4 Traffic Lanes	0.1636	0.0000
91 to 105 Daily Trains	0.3572	0.0000	150+ Daily Trains	0.2886	0.0000
5 to 6 Traffic Lanes	0.3510	0.0000	7+ Traffic Lanes	0.7923	0.0000
Industrial	0.0539	0.0001	Train Speed 70-79 mph	0.0325	0.0003
106 to 120 Daily Trains	0.2107	0.0004	Whistle Ban	0.0712	0.0008
76 to 90 Daily Trains	0.0569	0.0032	Train Speed 80-89 mph	0.1877	0.0082
Four Quad Gates/Barrier	0.1597	0.0000	Urban Other Principal Arterial	0.2061	0.0000

Table 10: Individual Variables that Passed Through Level 1 Screening

LEVEL 2 SCREENING RESULTS:

The second level of screening looks at the remaining variables in sets to determine which variables as paired, continue to have a positive relationship (coefficients greater than zero) to the five year accident history. A matrix was built comparing the 24 variables with each other; each variable has 23 pairings. Each column in the matrix represents the constant and the pairings below. The constants with the most pairings yielding coefficients greater than zero, and that were determined to be statistically significant by meeting the 0.05 threshold, were grouped and the top ten were moved forward for further analysis, as shown in Table 10. The top 10 represents those constants that are paired with 20 or more variables that yield coefficients greater than zero, and are statistically significant at a 0.05 threshold. See Appendix B for the pairing matrix and the regression models associated with the pairings.

Variable	**Number of Statistically Significant Pairings with Coefficients Greater than Zero**
Public	23
In City Limit	23
Highway Less than 75’ from Crossing	22
Commercial	22
Illuminated Crossing	22
Train Speed 70 to 79 mph	21
All Other Gates	21
Highway Speed 26 to 35 mph	21
3 to 4 Traffic Lanes	21
Industrial	20

Table 11: Variables that Passed Through Level 2 Screening

A further investigation into these top ten constants reveals several other physical and operational characteristics that when paired with the above, commonly occur. For example, public crossings as the constant were coupled with the remaining 23 variables. The coefficients for each of these pairings then tell us how much of an effect each of the 23 variables has when combined with public crossings. Each constant and set of 23 pairings were ranked based on their paired coefficient, the higher coefficient tells us generally that the combination has a stronger relationship with the five-year accident history. The projected mean of the pairings were then compared to the projected means of the characteristics, as individually evaluated, to confirm that the pairings did create a stronger relationship to the five-year accident history than the individual characteristics. The 5 pairings with the most improved projected mean, as paired, are shown in Table 11. See Appendix B for the matrix and tabulation of the projected mean and standard deviation for each pairing and individual variable.

Variable	**Pairing**	**Projected Mean**	**Standard Deviation**
Public		0.0464	0.4754
	Train Speed 80 to 89 mph	0.3333	0.8458
	7 or More Traffic Lanes	1.0000	1.1339
	5 to 6 Traffic Lanes	0.4928	1.0341
	150 or More Daily Trains	0.4483	0.8202
In City Limits		0.1102	0.5078
	7 or More Traffic Lanes	1.0714	1.1411
	91 to 105 Daily Trains	0.7167	0.8456
	150 of More Daily Trains	0.4407	0.8152
	Train Speed 80 to 89 mph	0.4348	0.7878
	61 to 75 Daily Trains	0.4009	0.7756
Highway Less than 75' from Crossing		0.1707	0.5152
	7 or More Traffic Lanes	0.6667	0.9847
	91 to 105 Daily Trains	0.6200	0.7796
	150 or More Daily Trains	0.3571	0.7449
	Train Speed 80 to 89 mph	0.5714	1.1212
	61 to 75 Daily Trains	0.3290	0.7307
Commercial Land Use		0.2207	0.5766
	Train Speed 80 to 89 mph	0.9231	1.2558
	91 to 105 Daily Trains	0.7188	0.7719
	7 or More Traffic Lanes	0.6667	0.9847
	Four/Quad Gate/Barriers	0.5217	0.7223
	106 to 120 Daily Trains	0.5000	0.6742
Illuminated Crossing		0.2332	0.6041
	7 or More Traffic Lanes	1.0000	1.1339
	91 to 105 Daily Trains	0.8438	0.8076
	Train Speed 80 to 89 mph	0.7778	1.1660
	Four/Quad Gate/Barriers	0.4384	0.7815
	61 to 75 Daily Trains	0.4154	0.8333
Train Speed 70 to 79 mph		0.1632	0.4863
	7 or More Traffic Lanes	1.6000	0.8944
	5 to 6 Traffic Lanes	0.7321	1.3002
	106 to 120 Daily Trains	0.6250	1.0135
	150 or More Daily Trains	0.5455	0.9045
	Urban Other Principal Arterial	0.4889	0.7999
All Other Gates		.01789	0.5155
	7 or More Traffic Lanes	0.9091	1.0445
	91 to 105 Daily Trains	0.5517	0.8035
	5 to 6 Traffic Lanes	0.5285	1.0813
	150 or More Daily Trains	0.4483	0.8202
	106 to 120 Daily Trains	0.4167	0.7945

Table 12: Level 2 Variables and Their Top 5 Pairings

Variable	**Pairing**	**Projected Mean**	**Standard Deviation**
Highway Speeds 26 to 35 mph		0.2182	0.5948
	7 or More Traffic Lanes	1.0000	1.1547
	Train Speed 80 to 89 mph	0.5882	0.4576
	150 or More Daily Trains	0.5882	0.9393
	91 to 105 Daily Trains	0.5833	0.7930
	61 to 75 Daily Trains	0.4918	0.9242
3 to 4 Traffic Lanes		0.2977	0.6761
	Train Speed 80 to 89 mph	1.2500	1.8930
	91 to 105 Daily Trains	0.9545	0.8985
	150 or More Daily Trains	0.8000	1.1464
	76 to 90 Daily Trains	0.5082	0.9420
	106 to 120 Daily Trains	0.4545	0.8202
Industrial Land Use		0.1941	0.5758
	5 to 6 Traffic Lanes	1.2000	1.3992
	150 or More Daily Trains	0.6667	1.1547
	Train Speed 80 to 89 mph	0.6667	1.1547
	91 to 105 Daily Trains	0.6471	0.9315
	61 to 75 Daily Trains	0.6389	1.1502

Table 12, Cont.

As shown in Table 11 above, other patterns arise. Table 12 notes that a train speed of 80 to 89 miles per hour and 91 to 150 daily trains is a common pairing.

Variable Pairing	**Number of Instances**
Train Speed 80-89 mph	9
91 to 105 Daily Trains	9
7 or More Traffic Lanes	8
150 or More Daily Trains	6
5 to 6 Traffic Lanes	5
106 to 120 Daily Trains	5
61 to 75 Daily Trains	4
Four Quad Gate/Barriers	2
76 to 90 Daily Trains	1
Urban Other Principal Arterial	1

Table 13: Most Commonly Paired Variables with the Top 10 Constants

Based on Level 1 and Level 2 Screening the characteristics that have the strongest relationship to the five-year accident history are:

- Public crossings
- Crossings within city limits
- Crossings with a perpendicular highway within 75’ from the crossing
- Crossings located in commercial land use
- Crossings that are illuminated
- Crossings with trains traveling 70 to 79 miles per hour
- Crossings protects by all other gates (no quad/four gate barriers)
- Crossings with highway speeds of 26 to 35 miles per hour
- Crossings that are crossed by 3 to 4 traffic lanes
- Crossings in industrial land use

When paired with other variables, the above listed have increased their projected mean and remain statistically significant by meeting the 0.05 threshold. However, for the majority of the pairings the standard deviation is larger than the project mean with the exception of two pairings:

- Crossings that are illuminated combined with daily train volumes between 91 to 105
- Crossings with highway speeds traveling 26 to 35 miles per hour combined with train speeds of 80 to 89 miles per hour

What this means is that within one standard deviation, the projected mean will still be greater than zero and therefore are likely to have a contribute to the five-year accident history.

LEVEL 3 SCREENING RESULTS:

As mentioned above, the addition of a passenger rail component to the ASA corridor would add to both the daily volume of trains as well as the speed of the trains. For Level 3 Screening multiple regression was used to focus on the grouping of variables that, when combined with train speeds between 80 and 89 miles per hours and train volumes of 46 to 60 daily trains, yield a statistically significant model by meeting the 0.05 threshold, with variables that can be used to analyze the ASA corridor. All regression models for Level 3 Screening can be found in Appendix C.

Increasing Speed as a Factor

A multiple regression analysis was conducted with the national dataset to determine which characteristics, combined with train speeds between 80 and 89 miles per hour, have the strongest relationship to accidents. The first level of review was a multiple regression of each characteristic in combination with the 80 to 89 mile per hour variable. The following tables list the combined total of the coefficients or projected mean number of accidents if all characteristics are present. For each categorical grouping, the strongest variable is passed along.

Type of Crossing

	Public Crossing	Private Crossing	Pedestrian Crossing
80 to 89 miles per hour combined with:	.2869	.0691	.0621

Location of Crossing

	In City Limits
80 to 89 miles per hour combined with:	.2558

Warning Device:

	None	X-bucks	Stop Sign	Other Sign	Traffic Light/ Bells/ Wigwags	Special Active Devices	Flashing Lights	All Other Gates	Four/ Quad Gate/ Barriers
80 to 89 miles per hour combined with:	.0444	.2492	.0991	.1875	.0674	.1256	.1569	.2486	.3460

Surrounding Land Use

	Open Space	Recreational	Farm	Residential	Commercial	Industrial	Institutional
80 to 89 miles per hour combined with:	.1059	.0827	.0660	.1572	.2766	.2443	.2197

Proximity to Perpendicular Highway

	75’ or less from Crossing
80 to 89 miles per hour combined with:	.2232

Smallest Angle of Railroad and Highway Intersection

	Angle 0-29	Angle 30-59	Angle 60-90
80 to 89 miles per hour combined with:	.1638	.1869	.1990

Number of Highway Traffic Lanes

	1-2 Traffic Lanes	3-4 Traffic Lanes	5-6 Traffic Lanes	7+ Traffic Lanes
80 to 89 miles per hour combined with:	-.0235	.3478	.5442	.9820

Highway Functional Class

	Rural Inter	Rural Other Princ Art	Rural Minor Art	R Maj Collect	R Min Collect	Rural Local	Urban Inter	Urban Other Free	Urban Other Princ Art.	Urban Minor Art.	Urban Collect	Urban Local
80 to 89 miles per hour combined with:	.0401	.1324	.1932	.1644	.1576	.1199	.0419	.1530	.4019	.3059	.2887	.2106

Local Regulations

	Whistle Ban
80 to 89 miles per hour combined with:	.2610

Number of Daily Trains

	0-15 Trains	16-30 Trains	31-45 Trains	46-60 Trains	61-75 Trains	76-90 Trains	91-105 Trains	106-120 Trains	121-135 Trains	136-150 Trains	150+ Trains
80 to 89 miles per hour combined with:	.0578	.1870	.2017	.3074	.2682	.2278	.5290	.4003	.4709	.1848	.4160

Visibility at Crossing

	Illumination
80 to 89 miles per hour combined with:	.2700

Highway Speed Limit

	Hwy less than 25 mph	Hwy 26-35 mph	Hwy 36-45 mph	Hwy 50+ mph
80 to 89 miles per hour combined with:	.1204	.2512	.2110	.1621

Table 14: Variable Grouping and Train Speeds between 80 and 89 miles per hour

All of the above highlighted variables are then considered together in a multiple regression model. The variables In City Limits, Smallest Crossing Angle between 60 and 90 degrees and Whistle Ban are removed as they do not meet the T-test threshold of 0.05. Table 14, below shows the resulting model when these variables are removed.

F-Value	33.87		
Probability of F	.0000		
Adjusted R-Squared	.0310		
Variable	**Coefficient**	**Standard Error**	**T-Test**
Speed 80 to 89 mph	.1420	.0700	.042
Public Crossing	.0725	.0152	.000
Four/Quad Gate Barriers	.1121	.043	.001
Commercial	.0522	.0111	.000
Perpendicular Hwy within 75’ of Crossing	.0192	.0093	.039
7+ Traffic Lanes	.6132	.1139	.000
Urban Other Principal Arterial	.1435	.0247	.000
91 to 105 Daily Trains	.3293	.0442	.000
Illuminated Crossing	.0577	.0120	.000
Highway 25-35 mph	.0480	.0127	.000
Constant	.0302	.0144	.036

Table 15: National Dataset Multiple Regression Model – Train Speed

Interpreting the Results:

Based on the multiple regression analysis, the number of accidents at highway-railroad crossings, where trains are traveling at speeds between 80 and 89 miles per hour, is increased when the above characteristics are present. The presence of 7 or more traffic lanes is the strongest contributor.

Along the ASA corridor however, several of the above characteristics are not present such as: crossings protected by Four/Quad Gate Barriers, crossing that cross 7 or more lanes of traffic, and the corridor does not currently experience train volumes of 91 to 105 daily trains. In addition there are only several crossings that are illuminated. When these variables are removed, the multiple regression model, as shown below, still remain statistically significant and can be applied to the ASA corridor.

F-Value	39.41		
Probability of F	.0000		
Adjusted R-Squared	.0205		
Variable	**Coefficient**	**Standard Error**	**T-Test**
Speed 80 to 89 mph	.1653	.0704	.019
Public Crossing	.0810	.0153	.000
Commercial	.0681	.0110	.000
Urban Other Principal Arterial	.1660	.0247	.000
Highway 26-35 mph	.0609	.0124	.000
Constant	.0413	.0143	.004

Table 16: Multiple Regression Model – Train Speed – Variables on the ASA Corridor

The results of the model in Table 15 tell us that the increase in train speeds on the ASA corridor between 80 and 89 miles per hours may increase the risk of accidents at crossings that are public; surrounded by commercial land uses; and cross an urban other principal arterial with speed limits between 25 and 35 miles per hours. Along the ASA corridor there is one crossing that meets all of these criteria. This crossing did not experience an accident between 2005 and 2009 and is equipped to handle train speeds up to 70 miles per hour. However if train speeds on the ASA corridor were to be increased to 80 to 89 miles per hour, the results from the national dataset analysis would predict that this crossing could experience an increase of 0.54 accidents over a five year period.

Increasing Train Volumes as a Factor

The current volume of trains on the ASA corridor is about 34 daily trains, which could be increased to about 58 daily trains if passenger rail is implemented. The same approach as above was used to determine which characteristics from the national dataset are most correlated to this volume of train traffic.

Type of Crossing			
46 to 60 daily trains combined with:	Public Crossing	Private Crossing	Pedestrian Crossing
	.2115	.0001	-.0162

Location of Crossing	
46 to 60 daily trains combined with:	In City Limits
	.1747

Train Speeds												
46 to 60 daily trains combined with:	0-9 mph	10-19 mph	20-29 mph	30-39 mph	40-49mph	50-59 mph	60-69 mph	70-79 mph	80-89 mph	90-99 mph	100-109 mph	110+ mph
	.0376	.0039	.0853	.0924	.1296	.1155	.1341	.1373	.3074	.0922	-.0276	-.0277

Warning Device									
46 to 60 daily trains combined with:	None	X-bucks	Stop Signs	Other Signs	Traffic Lights/ Bells/ Wigwags	Special Active Devices	Flashing Lights	All Other Gates	Four/ Quad Gate/ Barriers
	-.0247	.1797	.0244	.1109	-.0022	.0573	.0862	.1717	.2653

Surrounding Land Use							
46 to 60 daily trains combined with:	Open Space	Recreational	Farm	Residential	Commercial	Industrial	Institutional
	.0248	.0131	-.0039	.0834	.0834	.1620	.1428

Proximity to Perpendicular Highway	
46 to 60 daily trains combined with:	75’ or less from Crossing
	.1491

Smallest Angle of Railroad and Highway Intersection			
46 to 60 daily trains combined with:	Angle 0-29	Angle 30-59	Angle 60-90
	.0895	.1101	.1238

Number of Highway Traffic Lanes				
46 to 60 daily trains combined with:	1-2 Traffic Lanes	3-4 Traffic Lanes	5-6 Traffic Lanes	7+ Traffic Lanes
	-.1024	.2686	.4608	.9041

Functional Class of Highway												
46 to 60 daily trains combined with:	Rural Inter	Rural Other Princ Art	Rural Minor Art	R Maj Collect	R Min Collect	Rural Local	Urban Inter	Urban Other Free	Urban Other Princ Art.	Urban Minor Art.	Urban Collect	Urban Local
	-.0277	-.4536	.1213	.0882	.0833	.0403	-.0277	.0772	.3117	.2421	.2192	.1290

Local Regulations	
46 to 60 daily trains combined with:	Whistle Ban
	.1701

Visibility at Crossing	
46 to 60 daily trains combined with:	Illumination
	.2104

Highway Speed Limit				
46 to 60 daily trains combined with:	Hwy less than 25 mph	Hwy 26-35 mph	Hwy 36-45 mph	Hwy 50+ mph
	.0513	.1851	.1344	.0845

Table 17: Variable Grouping and Train Volumes between 46 and 60 Daily Trains

A multiple regression analysis of the highlighted variables reveals that two do not meet the T-test threshold of 0.05 including Smallest Crossing Angle between 60 and 90 Degrees and Whistle Ban. When removed and the remaining variables are run through the regression again, the model is a statistically significant model and all variables meet the T-test by meeting the threshold of 0.05.

F-Value	27.32		
Probability of F	.000		
Adjusted R-Squared	.0274		
Variable	**Coefficient**	**Standard Error**	**T-Test**
46 to 60 Daily Trains	.0908	.0187	.000
Public	.0784	.154	.000
In City Limits	.0198	.0099	.046
Train Speed 80 to 89 mph	.1653	.0701	.018
Four/Quad Gate Barriers	.1151	.0344	.001
Industrial	.0442	.0143	.002
Perpendicular Hwy within 75’ of Crossing	.0223	.0093	.017
7 or More Traffic Lanes	.6474	.1141	.000
Urban Other Principal Arterial	.1524	.0247	.000
Illuminated	.0571	.0124	.000
Highway Speed Limit 26-35 mph	.0467	.0127	.000
Constant	.0183	.0148	.215

Table 18: National Dataset Multiple Regression Model – Train Volume

Interpreting the Results:

Based on the multiple regression analysis, the number of accidents at highway-railroad crossings with train volumes that are between 46 and 60 daily trains, is increased when the above characteristics are present. The presence of 7 or more traffic lanes is the strongest contributor, as with the train speed analysis above.

The above variables were narrowed down to characteristics found along the ASA corridor which removed train speeds between 80 and 90 mile per hour, four-quad gate barriers, 7 or more traffic lanes, and illuminated crossings. When these variables are removed, the multiple regression model still remain statistically significant and can be applied to the ASA corridor.

F-Value	31.71		
Probability of F	.000		
Adjusted R-Squared	.0205		
Variable	**Coefficient**	**Standard Error**	**T-Test**
46 to 60 Daily Trains	.0917	.0188	.000
Public	.0816	.0154	.000
In City Limits	.0350	.0095	.000
Industrial	.0461	.0143	.001
Perpendicular Hwy within 75’ of Crossing	.0291	.0093	.002
Urban Other Principal Arterial	.1724	.0246	.000
Highway Speed Limit 26-35 mph	.0607	.0125	.000
Constant	.0168	.0148	.258

Table 19: Multiple Regression Model – Train Volume – Variables on the ASA Corridor

The results of this model tell us that the increase in train volumes on the ASA corridor between 46 and 60 daily trains may increase the risk of accidents at crossings that are public, within city limits, surrounded by industrial land use, is located within 75’ of a perpendicular highway, and is traversed by an urban other principal arterial with a speed limit between 26 to 35 mile per hour. There are no crossings that meet these criteria along the ASA corridor. A deeper look at the dataset for the ASA corridor reveals that there are no crossings that share both the industrial characteristic and that have a perpendicular highway within 75’ from the crossing (these variables will be discussed later in the implications chapter). If these two variables are removed, however, one crossing could be impacted by an increase in train volumes. If the train volume on the ASA corridor is increased to 46 to 60 daily trains, the number of accidents at this crossing could be increased by 0.45 accidents over a five year period.

It is interesting to note that the crossing identified with the train speed analysis is the same crossing indentified with the train volume analysis and contains all of the characteristics from both sets of analyses. This suggests that an analysis of the combined variables from the train speed and train volume analyses for the ASA corridor should follow, as shown below.

F-Value	33.20		
Probability of F	.0000		
Adjusted R-Squared	.0215		
Variable	**Coefficient**	**Standard Error**	**T-Test**
Train Speed 80 to 89 mph	.1736	.0703	.014
46 to 60 Daily Trains	.0954	.0188	.000
Public	.0736	.0153	.000
In City Limits	.0281	.0099	.004
Commercial	.0568	.0116	.000
Urban Other Principal Arterial	.1582	.0248	.000
Highway Speed Limit 26-35 mph	.0523	.0126	.000
Constant	.0320	.0145	.027

Table 20: Multiple Regression Model – Train Speed & Volume – Variables on the ASA Corridor

If the ASA corridor experiences train speeds between 80 and 89 miles and train volumes of 46 to 60 daily trains, the one crossing that is public, within city limits, surrounded by commercial land use, and is crossed by an urban other principal arterial with a speed limit between 26 and 35 miles per hour, could experience an 0.64 increase in the number of accidents at the crossing over a five year period.

CONCLUSION

Based on the analysis of physical and operational characteristics at highway-railroad crossings in the nation, crossings that are:

- Public;
- Located within city limits;
- Have a perpendicular highway within 75’ of the crossing;
- Are illuminated;
- Have train speeds between 70 and 79 miles per hour; are protected by gates (with the exception of four/quad gate barriers;
- Are crossed by highways with speed limits between 26 and 35 miles per hour;
- Crossings that are crossed by 3 to 4 traffic lanes; and
- Crossings that are surrounded by industrial land uses, are the characteristics that have the strongest relationship to the five-year accident history.

When paired, these relationships are enhanced by the presence of:

- Trains traveling 80 to 89 miles per hour;
- Train volumes of 61 daily trains or more;
- Crossings that are crossing by highways with 5 or more traffic lanes;
- Crossings that are protected by four/quad gate barriers; and
- Crossing that are crossed by urban other principal arterials.

The pairings that provide the most confidence, based on standard deviation of the regression, are illuminated crossings combined with daily train volumes between 91 to 105 trains, and crossings with highway speeds traveling 26 to 35 miles per hour combined with train speeds of 80 to 89 miles per hour.

The Level 3 Screening looked at the national database to tell us more about potential safety concerns at highway-railroad crossings along the ASA corridor if it experienced trains speeds between 80 and 89 miles per hours and train volumes between 46 and 60 daily trains. An increase in train speed on the ASA corridor could increase the risk of accidents at crossings that are public; surrounded by commercial land uses; and cross an urban other principal arterial with speed limits between 25 and 35 miles per hours by 0.54 accidents per crossing over a five year period. As mentioned above, one crossing on the ASA corridor meets these criteria. If the train volume on the ASA corridor is increased to 46 to 60 daily trains, the number of accidents at crossings that are public, within city limits, and crossed by an urban other principal arterial with travel speed limits between 26 and 35 miles per hour. The impact of these combined characteristics could increase accidents per crossing over a five year period by 0.45. When train speed and train volume are analyzed together, the national database analysis predicts that crossings along the ASA corridor that are public, within city limits, surrounded by commercial land use, and are crossed by an urban other principal arterial with speed limits between 26 and 35 miles per hour increase the number of accidents by 0.64 over a five year period.

Chapter 4: Implications of this Study

THE RAIL SAFETY ACT OF 2008 AND TXDOT'S SAFETY ACTION PLAN

Per the *Rail Safety Improvement Act of 2008*, the top 10 states in terms of fatal accidents at highway-rail crossings are now required to conduct accident prevention studies and develop a 5-Year Action Plan for reducing fatalities by August 2011 (TxDOT 2010b). As mentioned in Chapter 1, the state of Texas currently ranks number 2 in terms of the number of fatalities at highway-railroad crossings and number 1 for accidents in 2007, 2008 and 2009. A TxDOT study conducted from 2003-2007 crash data concluded that 63 percent of the crossings that experienced more than one accident also were equipped with train-activated gates and 41 percent had flashing lights and gates. Based on these results crossings experiencing multi-collisions and that have gates/flashing lights are recommended for evaluation for the Safety Action Plan (ibid). The analyses conducted for this report show several other physical and operational characteristics that should also be considered along the ASA corridor if new passenger rail it to be contemplated. These include:

- Public crossings,
- Crossing within city limits,
- Crossing surrounded by commercial land use,
- Crossings crossed by urban other principal arterials, and
- Crossings with highway speeds between 26 and 35 miles per hour

INDUSTRIAL USES AND PERPENDICULAR HIGHWAYS WITH 75' OF A CROSSING

According to Union Pacific, the railroad is studying safety at crossings where there is active industrial use and where highways are located within 75' of the crossing

(Schelbitzki 2010). According to *The Truckers Report*, the average length of a tractor trailer is between 70 and 80 feet long (The Truckers Report 2011). The concern is that a truck waiting to turn onto the perpendicular highway has not in fact cleared the crossing. Union Pacific's concern about this scenario can be justified by reading recent headlines. In 2010, 3 accidents within a span of two weeks occurred in Terrell, Texas between a tractor trailer and Union Pacific trains while the trucks were leaving a distribution center and while in cue to access a perpendicular highway (Gresham 2010). In 2009 in Wenatchee, Washington a UPS truck that was departing from a delivery was struck at a private crossing by a BNSF freight train while waiting in cue to access Malaga-Alcoa Highway (Riggs 2009). And in 2007 a tractor trailer was hit by an Amtrak train in Plant City, Florida while attempting to exit an industrial area over a private crossing (WSVN 7 News 2007). The results from the national analysis conducted for this study is in general concurrence that industrial uses and perpendicular highways located within 75' of the crossing have had a strong relationship to the five-year accident history. The review of the ASA corridor reveals that there are no crossings that contain both of these characteristics. However, the ASA corridor is located adjacent to the I-35 highway and is fronted with industrial uses. As such there is a potential for this pairing of characteristics to exist; as mentioned in Chapter 3, private crossings have the potential to be underrepresented as many of the national private crossings and all private crossings in along the ASA corridor are without a complete inventory.

SO WHAT ABOUT PRIVATE CROSSINGS?

While the national analysis did not reveal a strong relationship between private crossings and the five-year accident history, these results may not accurately represent the safety risk. As the articles reviewed above reveal, the incidents between tractor trailers and trains occurred at private crossings own by industrial uses. Along the ASA corridor there are 17 private crossings, 2 of which experience 1 accident each between 2005 and 2009. According to a review of state laws and regulations affecting railroad-highway grade crossings conducted by the FRA in October 2009, the state of Texas has no authority to regulate highway-rail crossings on private property (FRA 2009a). It appears that private crossings do have the potential to be a safety concern given that industrial uses and crossings with perpendicular highway with 75' of the crossing are strong indicators of risk. This study in addition to safety efforts being conducted by railroads may the support the need for a different approach to regulating private crossings.

PARTING THOUGHT ABOUT HIGH-SPEED RAIL ALONG THE ASA CORRIDOR

US Department of Transportation (DOT) policy generally supports the consolidation of crossings on active rail lines as a means to improve safety. Where at-grade crossings cannot be eliminated, DOT guidance recommends that "provisions be made to ensure that roadway approaches and crossing surface are suitable for all traffic, that sufficient warning is provided of the approach of trains, and that management of the highway-rail intersection is coordinated with other intersections involving nearby roads" (FRA 2009b). However this general approach may not be sufficient for corridors that carry high-speed passenger trains. FRA released *Highway-Rail Grade Crossing Guidelines for High-Speed Passenger Rail*, in November 2009 as an initial step in discussing the distinct safety requirements for high-speed rail service. According to their recommendations, safety risks are elevated on corridors that are used by both high-speed and slow speed trains, as would be the case with the current freight traffic using the ASA corridor (ibid). In addition, the preferred method to maintain safety for high-speed rail corridor is a sealed corridor with no at-grade highway-railroad crossings. While pursuing a shared-track scenario appears to be a fiscally-conservative approach to easing congestion and providing travel choice, the significant investments required to developed a sealed corridor between Austin and San Antonio as well as relocating the slower freight traffic, as has been suggested in Texas, would perhaps not be pursued due to financial constraints.

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