Tran-SET

Transportation Consortium of South-Central States

Solving Emerging Transportation Resiliency, Sustainability, and Economic Challenges through the Use of Innovative Materials and Construction Methods: From Research to Implementation

Research Incentive Programs for Closures of Public and Private Grade Crossings

Project No. 17PPLSU13

Lead University: Louisiana State University

Addressing Region 6 Transportation Needs

Final Report

December 2018

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16. Abstract

Vehicle-train crashes that occur at highway-rail crossings result in injuries, fatalities, and damage to equipment. In order to reduce the number of vehicle-train crashes, Federal Railroad Administration requires states which have challenges with crossing safety, including Louisiana, to develop a State Action Plan to improve grade crossing safety. Consequently, identification of specific solutions for improving safety at crossings was included in the 2015 Louisiana Transportation Plan as one of its objectives. This study seeks to identify and evaluate current and new incentive programs that encourage closure of at-grade railroad crossings to reduce the number of potential vehicle-train collision points, and hence improve safety. To accomplish this, a survey was designed and was distributed to personnel of state and railroad agencies. Survey responses from the DOTs revealed that currently, 16 states had no incentive programs for consolidation or closure of highway-rail crossings. Analysis of the survey data revealed that states without any incentive program had the least proportion of highway-rail crossing closures. The study revealed that cash incentives, while popular are not effective because although the Federal Government contributes to a state's effort in offering cash incentives for closure of public grade crossings, the amount is not substantial enough to be considered a significant incentive by most local governments. Also, track relocation, while effective is mostly impractical due to the high costs involved. A literature review revealed that having a mathematical model to guide on the selection of crossings for consolidation or closure provides sound scientific basis and are usually welcomed by the community. The research team identified three potential new incentives that could work well for Louisiana namely crime rate reduction incentives, greenness improvement programs, and the development of a grade crossing consolidation model that considers safety, among a plethora of other factors, to be used to prioritize crossings to be closed. However, additional work is required to validate these programs for statewide deployment.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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ACRONYMS, ABBREVIATIONS, AND SYMBOLS

AADT	Annual Average Daily Traffic
ADT	Average Daily Traffic
AI	Artificial Intelligence
AUC	Area Under the Curve
BNSF	Burlington Northern Santa Fe Railway
CPTED	Crime Prevention Through Environmental Design
DOT	Department of Transportation
DT	Decision Tree
EMS	Emergency Management Services
FRA	Federal Railroad Administration
FHWA	Federal Highway Administration
GB	Gradient Boosting
ICRC	Illinois Central Railroad Company
KCSRC	Kansas City Southern Railway Company
LaDOTD	Louisiana Department of Transportation and Development
MCA	Multi-Criteria Assessment
RF	Random Forest
RIMS	Research Information Management System
ROC	Receiver Operating Characteristics
Tran-SET	Transportation Consortium of South Central States
UDOT	Utah Department of Transportation
UPRC	Union Pacific Railroad Company
US	United States
XGB	eXtreme Gradient Boosting

EXECUTIVE SUMMARY

As of 2014, the total number of highway-rail crossings in the US was 250,711 out of which 38,818 (15.5%) were grade separated and the remaining 211,893 (84.5%) consisted of at-grade crossings. Incidentally, approximately 95% of all highway-rail incidents occurred at at-grade crossings. Vehicle-train crashes that occur at at-grade railroad crossings result in injuries, fatalities, and damage to equipment. It is therefore seen as a necessary safety measure, to decrease the number of at-grade railroad crossings by closing redundant crossings, thereby, reducing the number of potential collision points.

In view of this, this study aims to address part of the objectives of the 2015 Louisiana Statewide Transportation Plan, in particular to respond to calls for research into incentive programs that can be used to entice voluntary closure of public and/or private crossings. The study is in response to Tran-SET's (Transportation Consortium of South Central States) Problem Statement No. 17PPLSU13. The objective of this research project was therefore to synthesize current literature to identify incentive programs already being used and potential new programs that may offer promise in reducing the number of crossings in Louisiana and Region 6. It also aims to produce research outcomes which would assist Departments of Transportation (DOTs), local governments, railroad entities, and other industries that rely on rail service in their effort to reduce the number of potential vehicle-train collision points and offer a comprehensive reference document that highlights factors that impact closure of highway-rail grade crossings.

In order to achieve the study objectives, research was done on the websites of DOTs and railroad agencies to obtain information about existing incentive programs. Additionally, a survey was designed, using Qualtrics, and was sent to personnel of state agencies and railroad companies. This survey was distributed in order to obtain information that will allow the research team to evaluate the efficiency of current incentive programs, and to identify new programs. Researchers used data mining algorithms (including XGboosting, and Random Forest) to analyze factors that influenced crossing closure and to identify the importance of each factor. A second survey was then sent to safety experts in Louisiana to obtain information which justified the recommendations made by the researchers.

The study revealed that cash incentives, while popular are not effective because although the federal government contributes to a state's effort in offering cash incentives for closure of public grade crossings, the amount is not substantial enough to be considered a significant incentive by most local governments and affected communities. Track relocation was found to be the most effective but was also considered mostly impractical due to the high costs involved. The research team identified three potential new incentives that could work well for Louisiana namely crime rate reduction incentives, greenness improvement programs, and the development of a grade crossing consolidation model that considers safety, among a plethora of other factors, to be used to prioritize crossings to be closed. However, additional work is required to validate these programs for statewide deployment.

IMPLEMENTATION STATEMENT

The implementation stage of this research began with workforce development. Students - both graduates and undergraduates - were recruited for this project and offered stipends. This introduced the students to transportation issues and may further help attract them into the profession. The research team will also provide the study results to Tran-SET, who will make it available to all partner universities. There is the possibility that findings from this study can be used to supplement teaching material in transportation courses dealing with the safety and operation issues associated with railroad crossings.

The research team also discussed the process, the results, and the potential future works of this study through a webinar which was held on October 24, 2018. This webinar is archived on the Tran-SET's YouTube page and can be viewed directly through the Tran-SET's YouTube page.

Moreover, the research team has disseminated the results of this study through conferences, meetings, and/or workshops to educate and train professionals in the transportation industry. So far, presentations have been made at the 2018 Annual Meeting of the Transportation Research Board, the 2018 Tran-SET Conference, and the 2018 Annual Meeting of the American Association of Geographers.

1. INTRODUCTION

In the United States, highway-rail incidents at public and private crossings are a major concern. This is because of the fatalities and injuries resulting from such incidents, as well as the massive financial burden it places on state agencies and railroad administrators, due to delays in services and damage to trains, tracks, and other equipment. There are about 211,893 at-grade railroad crossings in the United States (US) with about 5,262 in the state of Louisiana. Preliminary statistics show that for 2017, there were 2,108 highway-rail incidents resulting in 827 injuries and 307 fatalities nationwide. In the state of Louisiana, 2017 recorded 87 collisions resulting in 31 injuries and six fatalities *(1)*. There is therefore a need to identify ways to improve safety, one of which is to close redundant public and private at-grade railroad crossings.

Out of the 5,262 at-grade railroad crossings in Louisiana, the number of private road/driveway crossings is 2,425 *(1)*. Where crossings are equipped with signalization and barriers, the safety hazard it poses, in terms of highway-rail incidents, is reduced. Unfortunately, most of the private road/driveway crossings lack signalization. Federal laws do not impose specific requirements for signalization of either public or private at-grade railroad crossings. It however recommends that engineering studies be conducted on a case-by-case basis to determine the need for signalization. Even then, this recommendation only applies to publicly-owned crossings and affects privately-owned crossings only when they are open to the public without access restrictions. Similarly, state laws primarily address crossings at public highways and it identifies circumstances under which the Louisiana Department of Transportation and Development (LaDOTD) can order a railroad company to provide signalization or other devices at such public crossings.

In addition to presenting safety concerns, there is a liability issue for both the state, railroad companies, and private owners depending on whether the highway-rail incidents occur at a roadway crossing that is open to public or private use. Liability also becomes an issue through the statutory obligations of the parties involved in an incident, regardless of whether the crossing is private or public. These issues can be costly and tend to hamper railroad operations and efficiency by diverting much needed resources towards litigation and compensation efforts.

In 2010, Louisiana was identified as one of the top 10 states with the highest number of reported highway-rail incidents. This led to the state being mandated by the Federal Railroad Administration (FRA) to develop a State Action Plan to improve safety at at-grade railroad crossings (49 CFR 234. 11) and to submit these plans to the FRA by August 27, 2011. Consequently, identification of specific solutions for improving safety at crossings, including closure of redundant at-grade railroad crossings, were included in the 2015 Louisiana Transportation Plan. In 2017, Louisiana ranked 7th among the top states with the highest number of reported highway-rail incidents. In the same year, approximately 64% of all such incidents across US occurred in the top 10 states. This shows that incidents at highway-rail grade crossings still present a challenge for Louisiana and there is the need to identify measures that will increase safety at Louisiana's highway-rail grade crossings.

This study seeks to identify and evaluate incentive programs already being used to encourage closure of redundant at-grade railroad crossings. It also seeks to identify potential new programs that may encourage closure of such crossings for Louisiana.

To achieve these objectives, the study relied on surveys administered nationwide to state transportation departments (DOTs), and railroad companies to obtain such information. It was impossible to obtain information on owner or private road/driveway crossings as they could not be reached to participate in the survey. It is anticipated that the research outcomes would include recommendations to assist state DOTs, local governments, railroad entities, and other industries that rely on rail service in their effort to reduce the number of vehicle-train collision points, and hence improve safety.

This report summarizes the research component of the study and reports on all research tasks undertaken and the recommendations from the research team. An Implementation Report will be submitted at the end of the project that will summarize the implementation phase activities including workforce development, education, and outreach activities related to this study.

1.1. Literature Review

The objective of this literature review was to identify any background information that would provide insights on the subject matter. Of particular interest, were the reasons for the need for closures of at-grade railroad crossings, a brief overview of current programs promoting safety at grade crossings, and an overview of factors that affect highway-rail grade crossing.

1.1.1. Need for At-Grade Railroad Crossing Closures

As of 2014, the total number of highway-rail crossings in the US was 250,711 out of which 38,818 (15.50%) were grade separated and the remaining 211,893 (84.5%) consisted of at-grade railroad crossings. These at-grade crossings were distributed as follows: public highway-rail crossings made up 61% (129,584), private highway-rail crossings made up 38% (80,120) and pedestrian-rail crossings made up the remaining 1% (2,819). Incidentally, approximately 95% of all highway-rail incidents occurred at at-grade crossings. It is therefore seen as a necessary safety measure, to decrease the number of highway-rail grade crossings by closing redundant at-grade railroad crossings, thereby, reducing the number of potential collision points.

As early as 1991, in a bid to reduce the number of vehicle-train collision points, the FRA set a goal to close 25%of all crossings nationwide within a ten-year period. The FRA has since not relented on their goals and has worked with state DOTs to close over 18,000 highway-rail grade crossings nationwide since 2008. Possible solutions to reduce the number of collisions at at-grade crossings are road active alarms, auditory alarms, in-vehicle alarms, visibility improvements, gates, corridors, grade separations, and highway-rail grade crossing consolidation and closures. Moreover, it is required to consider driver's behavior when it comes to crossing control programs *(2)*. This study focuses on the incentive programs adopted by state agencies that promote the closure of at-grade railroad crossings, and also analyzes the factors that state agencies consider when consolidating certain grade crossings. It is usually difficult to prioritize which highway-rail crossings to close or consolidate since every crossing

has a unique attribute. Moreover, most of the time, residents are opposed to closing a crossing because they believe it will inconvenience them *(3)*.

The FRA believes that consolidating "unneeded" or redundant crossings is crucial to public safety and economic development as it improves safety and reduces congestion. In its 1994 crossing consolidation manual, the FRA advocates for a corridor approach to be used when considering crossing consolidation. The corridor approach evaluates multiple crossings along a rail line. This method has proven to be effective by involving the affected community in its analyses and in reducing overall project costs by lessening the administrative burden on all involved parties *(4)*. Even though the corridor approach calls for a more comprehensive approach, safety has remained the basis for highway-rail grade crossing consolidation in most states.

The FRA has not mandated any state agency to offer a specific incentive program to its citizens to ensure closure of at-grade railroad crossings. Therefore, each state agency maintains its own program(s). Primarily, incentive programs have been in the form of financial incentives which fund a safety project for the affected owner, with each state agency having its own conditions attached. With limited state budgets, it is imperative that a state agency identifies the balance between the amount of available budget for incentives and that for its other programs. Each state has to therefore continually evaluate its incentive programs to determine what offers the best value to its citizens. However, to date, there is no such study that synthesizes all of the current incentive programs offered by each state. Maintaining such a document will provide an easy and comprehensive means for state agencies and railroad entities to evaluate their programs in relation to other states nationwide.

1.1.2. Current Safety Programs

A number of programs have been designed to promote safety at at-grade railroad crossings. In the context of this study, only two are discussed: the control and consolidation programs.

Highway-Rail Crossing Control Program: This program promotes safety using three key areas: 'Engineering', which involves preventing entrance into crossings and/or using better devices to alert people, while considering the balance between risk and cost; 'Education', to increase the public's awareness about the risks of highway-rail grade crossings; and finally, 'Enforcement', to establish laws in accordance with safety improvements *(5)*. Various methods have been considered to aid in eliminating the risks of at-grade railroad crossings, such as using pavement markings *(6)*, passive and active alarms *(7, 8)*, obstacle detection *(9)*, gates *(5, 10)*, temporary closures, grade separation *(2)*, corridors *(11)*, in-vehicle crossing alarms *(12)*, and finally road consolidation *(13)*.

According to the Federal Highway Administration handbook *(14)*, *active traffic alarms* are advanced and highly noticeable alarms that are activated when trains approach a crossing. They notify drivers of approaching trains using flashing lights and prevent vehicles from entering the crossing while the train passes, using automatic gate arms. The effectiveness of active alarms was evaluated by conducting before and after studies at a number of crossings. Generally, active alarms improved the safety of these crossings. It was however mentioned that active alarms could be distracting to drivers.

Improving pavement markings is another way to enhance safety at at-grade railroad crossings. This approach aims at changing driver stopping behavior especially within the dynamic envelope when a train is approaching. Results from research undertaken indicate that the addition of the dynamic envelope pavement markings and modified signage reduce the number of vehicles that stop within the dynamic envelope zone and increase the number of vehicles that stop safely behind the stop line *(6)*.

One of the most common crossing control programs in the US is the *gate arm installation* program. These gates can be manned or unmanned (automatic) although unmanned gates are more common. Crossings with gates are generally believed to be safer than crossings with passive alarms or flashing lights *(5)*.

The obstacle detection technologies is another safety improvement method which uses a collection of multi-static radars exploiting the ultra-wide-band, image scanner concepts, LIDAR, and 3D laser range finders at highway-rail grade crossings *(9)*. Using the aforementioned tools, trains are notified about the presence and sizes of obstacles present during operation. Govoni et al. *(9)* used simulations to confirm the applicability of these technologies.

In order to improve safety at high risk at-grade railroad crossings, *corridor planning projects* have been employed. The *corridor planning projects* seek to provide railroads with commuter rail services that fulfill the required design and safety standards *(11)*. The state of North Carolina was the first to undertake a corridor planning project *(5)*. In order to successfully plan the project, a relative priority rank for each crossing was calculated to measure risk. The risk was calculated by analyzing multiple factors which could affect the safety of highway-rail grade crossings such as traffic characteristics, crash history, road/rail type, the design of crossings, highway/track geometry, and passive/active alarms.

Ideally, in order to decrease the number of train-vehicle collisions, the best method to use would be highway-rail grade separation *(11)*. This route is seldom taken because of the high cost of analyzing and implementing *grade separation projects*. A more "modern" approach is suggested by Landry et al. *(12)* where the plausibility of *in-vehicle auditory* alerts to warn of approaching trains is explored *(12)*. Technological advancements have made it less difficult and inexpensive to access GPS and smartphones hence the idea of having in-vehicle auditory alerts is catching on.

All of the above crossing control programs are being implemented in different states according to the existing needs, time, and budgets. However, the consolidation programs are believed to be a promising approach to decrease the number of train-vehicle collisions. Generally, consolidation programs seek to consolidate the distribution of at-grade railroad crossings in an area to decrease collision probabilities.

Grade Crossing Consolidation Program: In order to maintain safety at highway-rail grade crossings, various multidisciplinary incentive programs exist between the federal, state, and local governments, as well as railroad companies, with the purpose of funding project costs. The aim is to strike a balance between costs and improving a crossing's safety while considering the environmental, economic, and social aspects. Some of the incentive programs

are put in place to solely aid consolidation projects, due to their high effectiveness compared to other safety improvements. Consolidation programs seek redundant or unsafe crossings that are deemed insignificant or redundant enough to warrant closure. Consolidation programs can be informed by consolidation models that consider external factors by developing rating formulae to determine which crossing is best suited for closure.

Road consolidation, or closure, is known to be a very cost-effective way to prevent future collisions, while simultaneously reducing environmental pollution *(15)*. Community cohesion and land-use applicability may be affected inversely by this program. However, a closure is strongly encouraged if there is an alternate route. Community agreement to crossing closure is difficult to secure due to the assumptions that residents have about the loss of property *(3)*. Strong justification is usually needed for closures hence the need to investigate the relationship between the existence of redundant crossings and factors such as safety *(3)*, pollution, economy, community cohesion, and quality of life. This justification can be used as an incentive to encourage the community to show support for crossing consolidation, as well as to come up with a prioritization model for highway-rail grade crossings based on whether they are public or private, the level of development in the area, and whether it is in an urban or rural locality *(5)*. Presently, each US state has a different action plan with respect to private crossings *(1)*. For instance, in Virginia, the opening of private crossings is forbidden. On the other hand, Ohio provides a resident, who owns fifteen or more continuous acres of land, separated by a train track, with an appropriate and sufficient private crossing. Previous studies have discussed consolidation laws and regulation with regards to public crossings, but the consolidation of private crossings is a research gap that needs more attention.

Generally with regards to highway-rail grade crossings, the best candidates for consolidation are those with high risk and a low environmental impact *(3*). An example of a high-risk crossing is one where the possibility of getting killed when using a crossing at the wrong time is high. From railroad agencies point of view, risk is also related to the cost of damaged equipment. Consolidation programs therefore try to reduce risk while improving rail services. Another criterion for selecting candidates for closure is low consolidation impact. One of the primary factors that changes after a crossing closure is street accessibility which minimizes access to residential, industrial, recreational areas *(13)*.

According to the Guidelines for Highway-Rail Grade Crossings *(4)*, the states that have had the most highway-rail incidents must implement their own model with the aim of removing redundant crossings while simultaneously improving safety and budget objectives. A number of various factors have been used by different states, such as economic and transportation factors (collision history, vehicle delay, operating cost, road traffic, train traffic, type and size of train, grade separation cost, accessibility/connectivity, crossing angle, topography, sight distance, and construction cost, vegetation, development level), social factors (land use and type of property, community cohesion, visual severance, geographic distribution, noise, crime, visual amenity (underpass, overpass), site of social significance), and environmental factors (air and water quality, site of environmental significance) *(2, 3, 8, 15)*.

In one of the holistic studies undertaken, Hans et al. *(15)* worked on prioritizing crossings for consolidation by using the six quantitative factors of traffic volume, heavy-truck traffic

volume, road system, proximity to schools, proximity to emergency medical services, and out-of-distance travel *(15)*. These were weighted differently based on the location's level of development and whether it was urban or rural. Factors other than safety were also discussed in their research, but all the factors were not used to evaluate and rank the crossings. For each factor there were sub-factors related to each other, which meant that there could be correlation between factors. For instance, the road system has a direct effect on traffic volume, likewise the proximity to special land use may change the traffic volume at a different time. Due to lack of information, some factors (such as humped crossing, crime, noise and visual amenity, land use, community cohesion, etc.) were not used in some crossing control projects.

In another study, Arellano et al. *(16)* considered corridor-levels when prioritizing crossings. In their study, for a corridor with n total crossings, the average probability of having m crashes is calculated. However, the study considered each crossing separately when rating them for closure. By doing this, the mobility and safety factor reliability was increased, though only one sub-factor was used as the safety factor. In previous works, the accessibility factor was calculated by detour distance, which uses just one nearest grade separated distance. Likewise, the safety factor was obtained separately using the sub-factors of AADT, peak train per day, speed, number of main tracks, and accident history. It is beneficial to use a corridor approach for crossings, as well as to utilize safety and mobility factors in one equation to reduce the correlation of different factors *(17)*. The problems of factor correlation and reliability could be considered as a research gap.

In another study carried out in Australia, a country that experiences a lot of conflicts at highway-rail grade crossings *(18)*, the correlation between factors was reduced by using Multi-Criteria Assessment (MCA). For factors such as noise and visual amenity where the appropriate data may not be available, the qualitative indicators were based on the objective rating of the relevant effects. The crossings in this assessment, whether local or urban and/or private or public, are considered under the same factor sensibility. This means that the result may have errors depending on the context of each crossing.

In another study in Europe, Cirovic and Pamucar created a neuro-fuzzy decision support system using twenty experts' knowledge on road and traffic safety to enable the quantification of criteria and select the best alternative crossing for closure *(19)*. In this study however, the correlation between the 8 modeled factors was not considered.

All these studies go to show that consolidation models have been used to guide consolidation programs geared to close redundant at-grade railroad crossings. Such approach is therefore scientifically justifiable and may provide a measurable assessment of any proposed closure.

2. OBJECTIVES

This study aims to address part of the objectives of the 2015 Louisiana Statewide Transportation Plan, in particular to respond to calls for research into incentive programs that can be used to entice voluntary closure of public and/or private crossings. The study is in response to Tran-SET's Problem Statement No. 17PPLSU13.

The objective of this research project was therefore to synthesize current literature to identify incentive programs already being used and potential new programs that may offer promise in reducing the number of crossings in Louisiana and Region 6.

It is anticipated that the research outcomes would include recommendations to assist DOTs, local governments, railroad entities, and other industries that rely on rail service in their effort to reduce the number of potential vehicle-train collision points. This research used surveys which were administered nationwide to state transportation departments and railroad companies to identify incentive programs being used and also new programs that could be used.

In summary the objectives are:

- To address part of the 2015 Louisiana Statewide Transportation Plan,
- To synthesize current literature to identify incentive programs already being used,
- To identify potential new programs that offer promise in reducing the number of crossings, and
- To offer a comprehensive reference document that highlights factors that impact closure of at-grade railroad crossings.

3. SCOPE

This report demonstrates the research phase activities. The study area was limited to the US in order to recommend appropriate incentives for Louisiana. The research team used online material from websites of state DOTs, administered surveys, and data from the Research Information from Management System (RIMS) database in this study. It was impossible to obtain information on owners of private highway-rail grade crossings so subsequently, surveys were administered to only public officials and railroad administrators.

4. METHODOLOGY

Research was done on the websites of DOTs and railroad agencies to obtain information about existing incentive programs. Additionally, a survey was designed, using Qualtrics, and was sent to personnel of state agencies and railroads. This survey was distributed in order to obtain information that will allow the research team to evaluate the efficiency of current incentive programs, and to identify new programs. Finally, researchers used data mining algorithms to analyze factors that influenced closure of at-grade railroad crossings (crossing closure) and to identify the importance of each factor. Details of these activities are as follows:

4.1. Online Research

To be able to document the existing incentive programs in the US, the research team searched for information from the websites of DOTs and railroad agencies. The goal was to get as much information as was available through online data resources. Some of the information needed was not available online, hence, the research group decided to distribute a survey among state DOT personnel and railroad safety experts in the US.

The major advantage of online research is its low cost, but the main drawback, especially for this research is that there is a lot of material that has to be sifted through in order to get the exact information required. Another drawback is that sometimes the available information is out-of-date. To save time and money, the research group first conducted a two-month online search to gather publicly available information on incentive programs in the US. Information on existing incentive programs was obtained for all states except Montana, which had no information online. This information is summarized as below:

Cash Incentive: This offers cash to aid highway-rail grade crossing projects which is provided either by state authorities or FRA. The most successful and known incentive program offered by FRA is Section-130 by which each state is required to identify highway-rail grade crossings that may require safety improvement. However, some DOT's believe that the cash amount offered is not enough and have requested an increase in this fund. This is reflected in the survey responses from Indiana DOT, New Jersey DOT, and Norfolk Southern Company.

Nearby Crossing/Road Improvement: This program requires that DOTs must implement specific maintenance requirements such as road surface improvement, changing passive alarms to active alarms, and building bigger roads in term of number of lanes at affected or identified highway-rail crossings. Sometimes, cash incentives are used to fund a nearby crossing or road improvement program. For instance, the section 130 program funds protective device installation for highway-rail crossing improvement *(20)*.

Nearby Crossing Grade Separation: This program seeks to build either overpass or underpass routes for grade separation at an identified highway-rail crossing. This approach is also called Vertical Track Relocation. Several rating formulas have been previously developed to generate candidate lists for crossing grade separation by finding the most valuable crossing in a neighborhood so as to separate highways from railroads.

Track Relocation: This program consists of a rail line being horizontally moved to another location far from dense urban places. The main disadvantage of this method to a community

is the limitation of economic development. When a track is moved, accessibility to industrial companies, freight and rail passenger operations may be affected. On the other hand, removing tracks increases access to streets, resulting in less motor vehicle and pedestrian traffic, improved safety, and higher community quality of life *(21)*. Track relocation usually results in many highway-rail grade crossing closures. This program took effect on July 11, 2008 *(21)*.

4.2. Survey Design

The survey design has a major impact on the quality of the survey responses in that it may negatively or positively impact the inference drawn for the study. Since this study was highly dependent on the survey approach, care was taken in the design of the survey and its distribution in order to obtain reliable responses.

4.2.1. Contact Verification

The research team sought to obtain contact details for a railroad safety personnel in each of the 50 US states DOTs. Where information on such personnel was not readily available on the state DOT's website, several personnel from that state DOT where contacted via email and/or phone to obtain the content detail of the relevant personnel. In addition, experts working with railroad agencies in each of the 50 states were sought. Again, each contact was verified through phone call or email to be either a railroad safety personnel or someone responsible to properly complete the survey. Altogether, 52 verified DOT personnel and 240 verified railroad personnel were contacted for this survey.

4.2.2. Design of Questionnaire

The questionnaire was designed with Qualtrics. Qualtrics, founded in 2002, is an online survey software used to collect and analyze data for various purposes. The Qualtrics platform has a very user-friendly environment equipped with quantitative statistical analysis tools for easy interpretation of responses. The respondents were made aware of the existing and possible incentive programs for closures at the beginning of the survey. These programs were: cash incentive, nearby crossing improvement, nearby crossing grade separating, nearby road improvement, and track relocation.

The survey comprised the following questions:

1. Some incentive programs for railroad closure/consolidation are Cash Incentives, Nearby Roadway/Crossing Improvement, and Track Relocation programs. Does your state/ agency offer or administer an incentive program(s) for closure of at-grade crossing?
2. Which type of incentive program(s) does your state/ agency offer or administer? Please provide any information on your program(s).
3. How long has your program(s) been in effect?
4. How effective is your incentive program(s) in achieving your goals of railroad closure/ consolidation?
5. In your view, what are the reasons for not having a very effective program(s)?

In this survey, experts were expected to select any incentive program(s) they used in their state or agency. The respondents could then rate the effectiveness of each program(s) they selected and point out the main weakness(es) within the program(s). Afterwards, the mean overall

effectiveness of each program was calculated in Qualtrics data analysis section. The research team also validated the Qualtrics effectiveness value by implementing another quantitative method, based on the incentive programs offered by each state and the percentage of closed crossings in that state.

5. FINDINGS

5.1. Survey Responses

The survey responses from railroad agencies and DOTs of each state are illustrated in Figures 1 through 6. These figures were produced based on the survey responses received. Approximately 52% (28 out of 52) of DOT personnel and 14% (33 out of 240) of railroad agencies responded to the survey. Altogether, responses were obtained from 42 states where either a state DOT and/or a railroad agency expert responded. Figure 1 shows a US map that illustrates the 12 states where no responses were obtained at all and the remaining 38 states that responded to the survey. The 12 states with no response were California, Connecticut, Hawaii, Rhode Island, Pennsylvania, Arizona, Nevada, Iowa, Missouri, New Hampshire, Maryland, and Vermont.

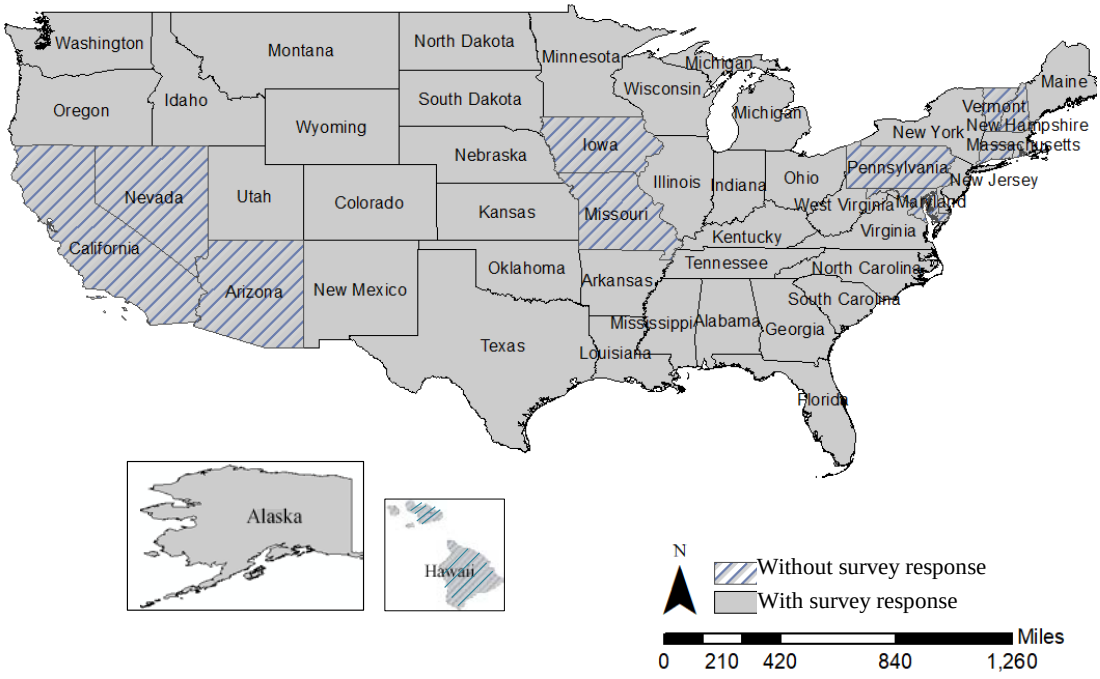

Figure 1. States with or without survey response.

5.2. Incentive Programs

Out of the 38 states with survey responses, 22 reported having some form of incentive program while the remaining 16 states reported having no current incentive programs. States without incentive programs were Maine, Massachusetts, Colorado, New Mexico, North Dakota, South Dakota, Washington, Wyoming, Idaho, Oregon, Louisiana, South Carolina, Arkansas, Delaware, Virginia, and West Virginia.

Figure 2 shows a US map illustrating the states with or without a form of incentive program. It is worth noting that for Louisiana, responses were obtained from both a state DOT personnel and a railroad expert, specifically Burlington Northern Santa Fe Railway (BNSF). The state DOT personnel stated that there was no incentive program, the railroad expert noted that BNSF

in particular offered a form of incentive. Figure 2 reflects answers responded by state DOTs to reflect statewide policy.

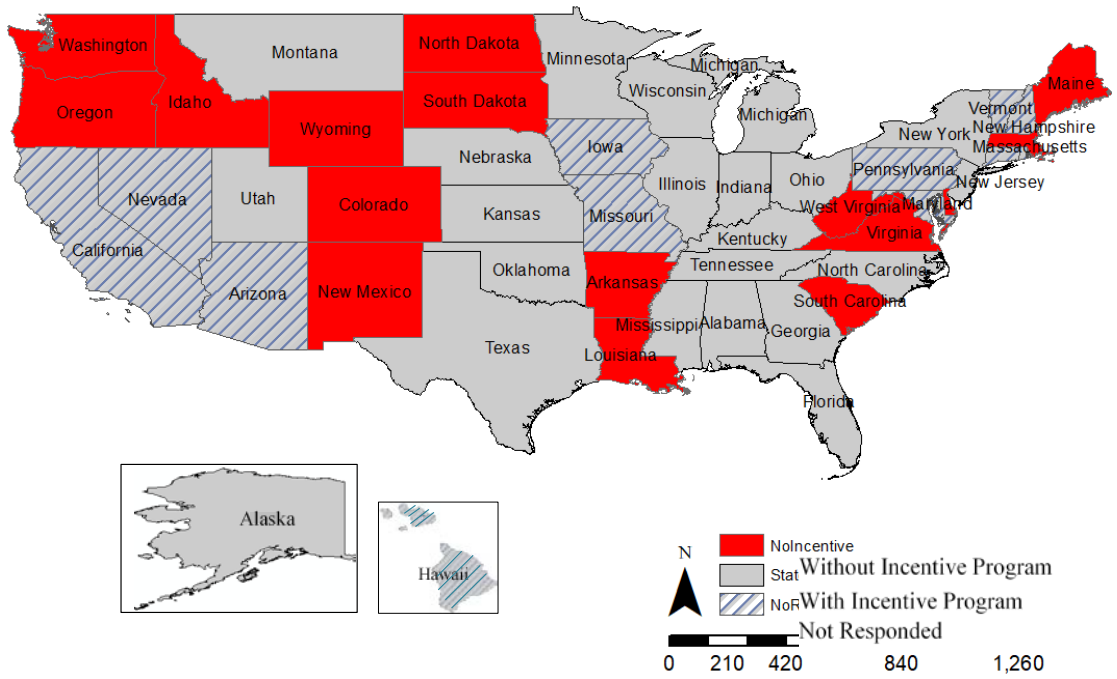

Figure 2. States with or without incentive programs.

5.3. Cash Incentive Program

Cash incentives are offered to communities that will be affected by highway-rail crossing closures. The funds are usually sourced from the federal government via Federal Section 130 funds. These are monetary payments up to $7,500 that the federal government contributes to a state's effort in offering cash incentives for closure of public at-grade railroad crossings. This amount is not sufficient to be considered a significant incentive by most local governments who face public backlash from crossing closures. The cash incentive is not worth the trouble according to residents who usually mount heavy local political pressure against closures of grade crossings.

Figure 3 shows a US map illustrating states with or without a cash incentive program. It can be seen that 10 out of 38 states that responded offer some sort of cash incentive. These states are Nebraska, Michigan, Minnesota, Wisconsin, New Jersey, Mississippi, Tennessee, Ohio, Illinois, and North Carolina. Louisiana does not offer any form of cash incentive program.

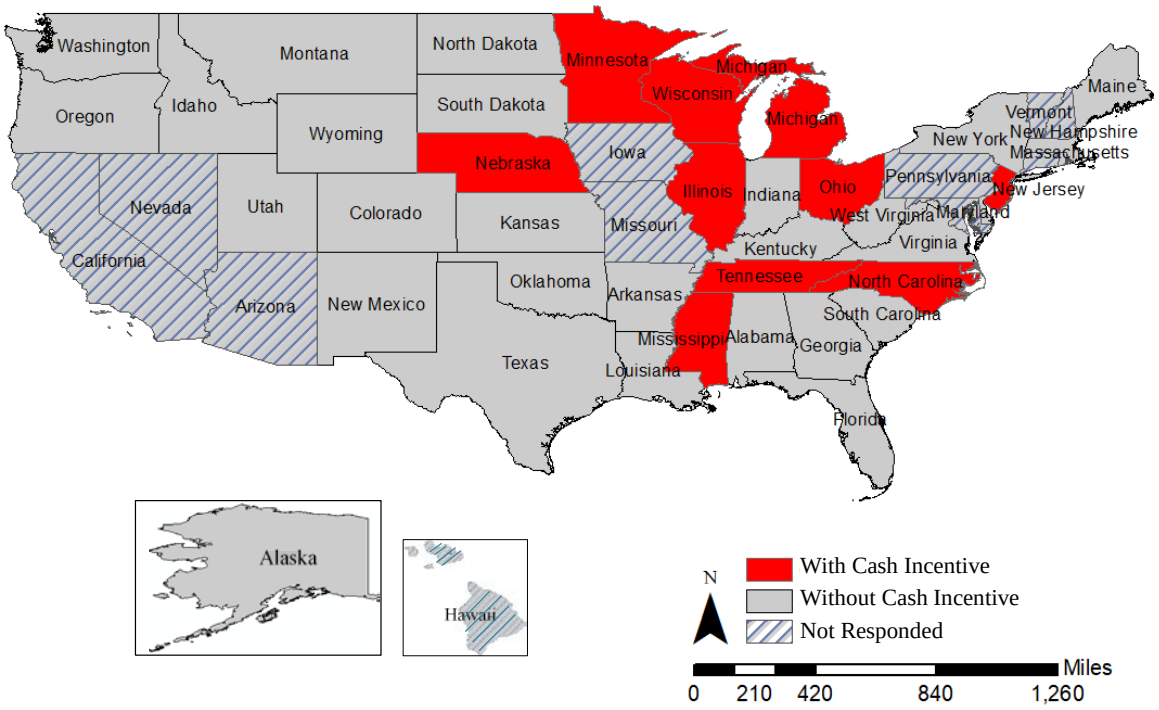

Figure 3. States with or without cash incentive programs.

5.4. Road Improvement Program

The road improvement program is considered one of the attractive incentive programs for residents. When a closed crossing gives rise to unfavorable or undesirebale results such as causes traffic congestion because of a sudden access route, a road improvement incentive can be offered to alleviate the traffic congestion problem. Road improvement programs usually offer widening, geometric improvement at/near crossings, paving improvement, new location of roads, improved surface condition, and provision of active alarms at crossings. The goal is to improve connectivity for road users over fewer highway-rail grade crossings in an area to mitigate for crossing closures in a nearby vicinity.

Figure 4 shows a US map illustrating the states with and without a road improvement incentive program.

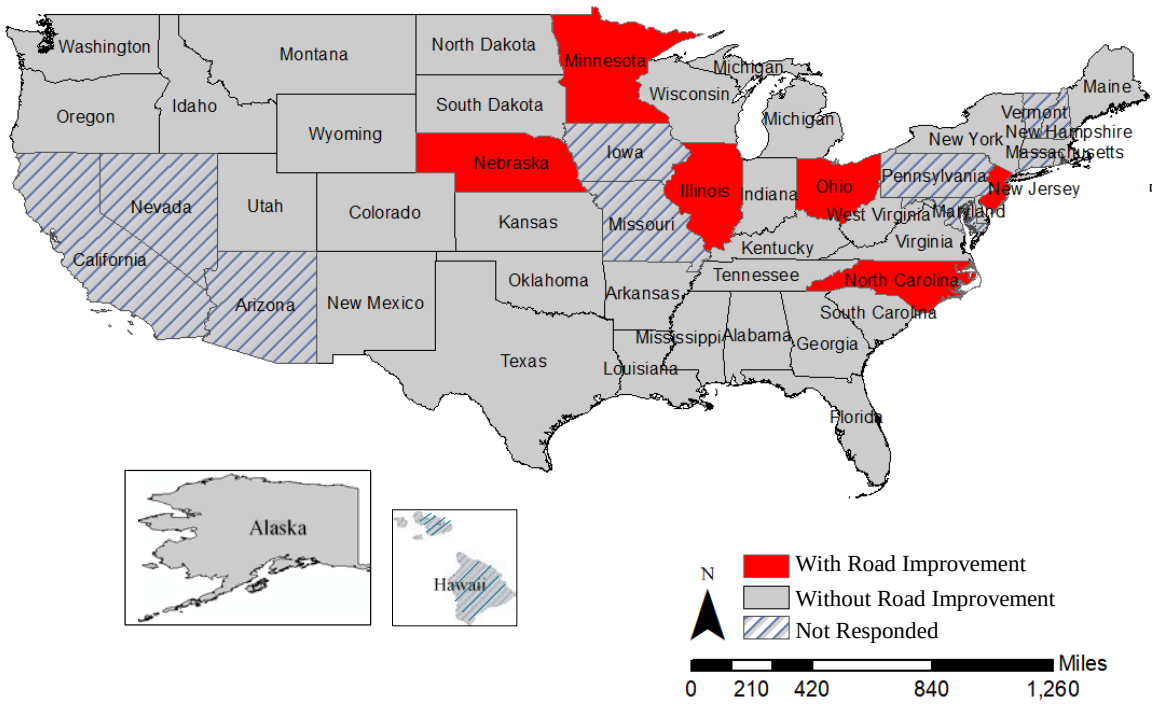

Figure 4. States with or without road improvement programs.

It can be seen that out of the 38 states that had a survey response, only six states reported having some form of road improvement incentive program. These are Minnesota, Nebraska, North Carolina, Ohio, Illinois, and New Jersey. In Illinois, remote monitoring devices are used to alert any failure in passive or active warning device. Moreover, several plans are available within the state seeking to create roadways between closed crossings and their nearby open crossings. Railroad safety experts believe that improvements such as surface reconstruction and profile improvement of nearby open crossings, usually increases safety at these nearby crossings.

For **Louisiana**, four survey responses were obtained from LaDOTD, BNSF railway, Delta Southern Railroad, and Watco Companies LLC in Louisiana. While BNSF railway mentioned that they had improvement-based incentive programs for closure of railroad crossings, the other three respondents including LaDOTD said they had none. The BNSF railway personnel commented that:

> *"The Railroads incentive funds available to public roadway authorities (for Public Road crossings) and private landowner (Private Road crossings) to assist with funding of roadway improvements (performed by the roadway owner) associated with the closure of at-grade crossings and re-routing of vehicular traffic to alternate open crossings. The railroad's crossing closure funds are to be used at the discretion of the roadway owner."*

Figure 4 reflects the response from the state DOT personnel.

5.5. Grade Separation Program

Grade separation programs seek to find the best crossing for grade separation. The cost of constructing a new bridge or reconstructing an old one for either underpasses or overpasses is

very high. This approach therefore appears to be not very practical due to the high cost involved. Figure 5 shows a US map illustrating the five out of 38 states (13 %) that reported having offered a grade separation incentive in the past. The remaining states are those that either did not respond to the survey or have not offered a grade separation incentive program. The five states are Nebraska, Illinois, Ohio, Tennessee, and North Carolina.

Louisiana does not offer any form of grade separation incentive. Work items in grade separation include bridge construction, utility relocation, right of way aquisition, safety lighting, traffic signals, and connecting road construction.

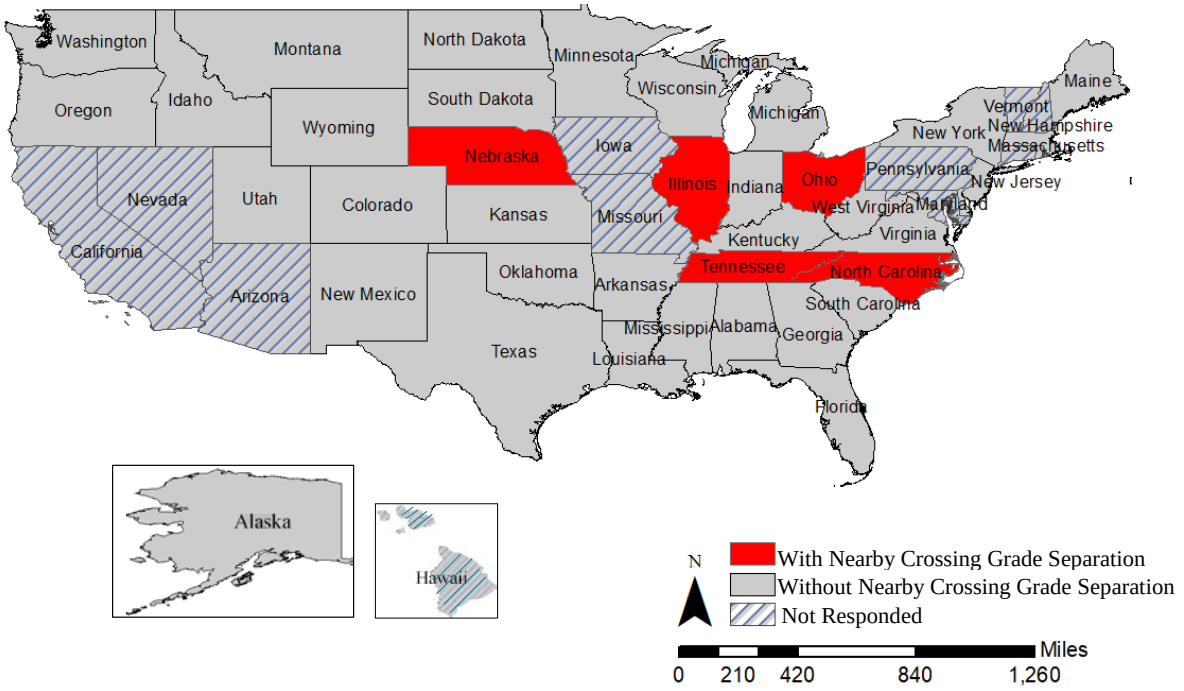

Figure 5. States with or without grade separation programs.

5.6. Nearby Crossing Improvement Program

The nearby crossing improvement program is another improvement-based approach where the safety and conditions of a crossing near a closed crossing are improved. Nearby crossing improvements are done to minimize traffic congestion. Also surface conditions are improved, bridges reconstructed, roads widened, and active alarms are set in this approach. Safety personnel from the Ohio Rail Development Commission mentioned that residents did not consider crossing improvements as an incentive since they believed that crossings should be improved regardless. Nearby crossing improvements are considered a real incentive when the community is looking for other improvements like quiet zones. Figure 6 shows a US map illustrating the 10 out of 38 states (26.3%) that reported having offered a nearby crossing improvement incentive in the past.

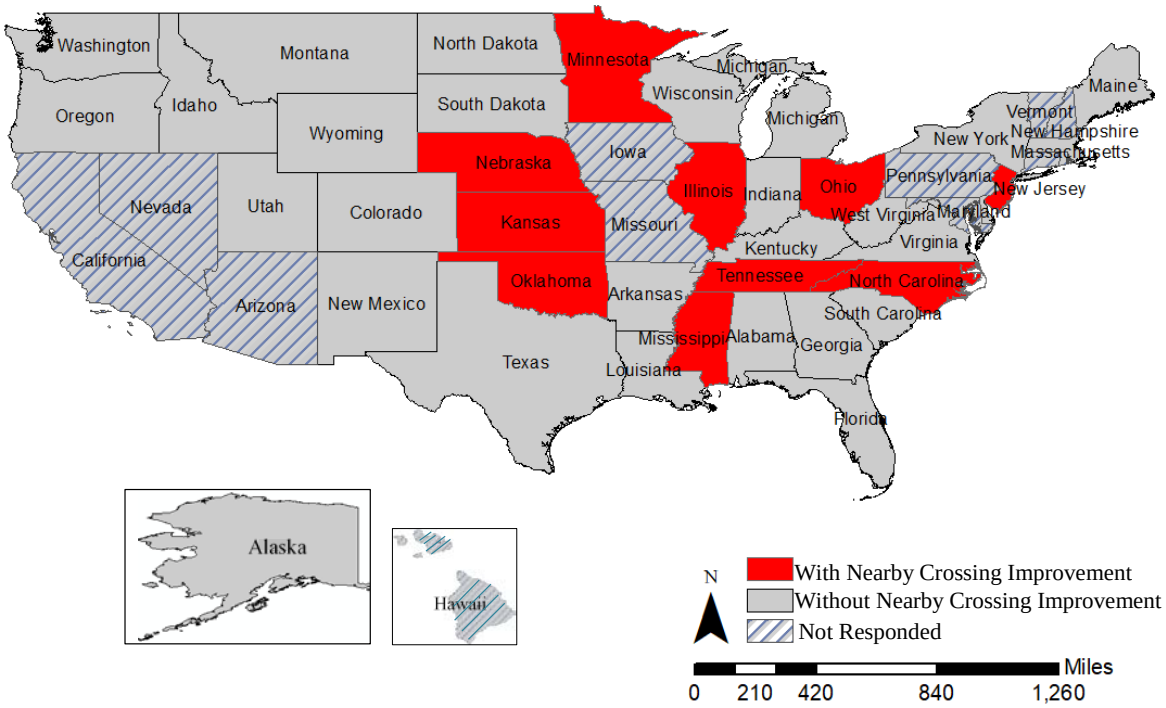

Figure 6. States with or without nearby crossing improvement.

The states using this improvement are Minnesota, Nebraska, Kansas, Illinois, Ohio, Tennessee, North Carolina, New Jersey, Oklahoma, and Mississippi.

In **Louisiana**, as previously mentioned, BNSF railroad agency stated nearby crossing improvement was an incentive used in the state for consolidation. However, LaDOTD asserted that they had no incentive program for crossing consolidation.

5.7. Track Relocation Program

In addition to improvement-based and cash incentive programs, this is another incentive program which focuses on the relocation of tracks. Track relocations are rarely offered due to the cost involved. The track relocation incentive is said to be implemented in order to switch operations away from congested urban areas.

Figure 7 shows a US map illustrating the states with or without a track relocation incentive program. In the figure, it can be seen that four out of 38 states reported having offered track relocation programs to encourage crossing owners to embark on consolidation programs. Michigan, Ohio, North Carolina, and Kansas are the states that use this incentive for crossings closure.

Louisiana does not have any form of track relocation incentive program, however, siding track removal has taken place in some industrial neighborhoods.

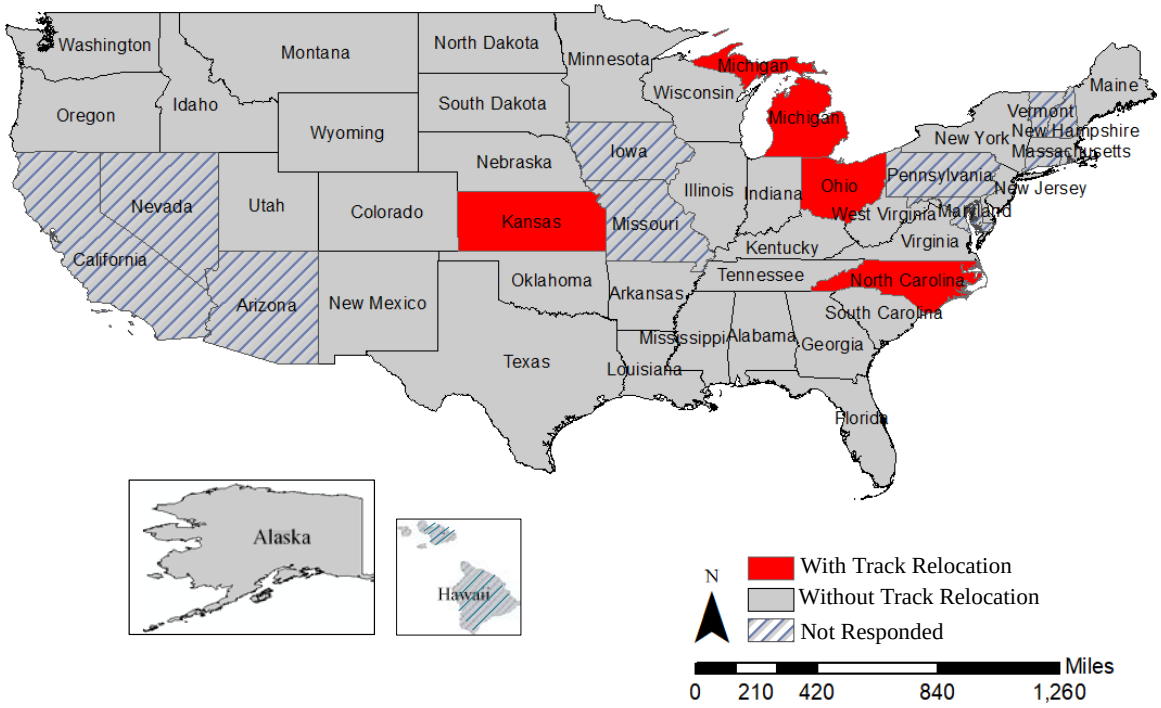

Figure 7. States with or without track relocation programs.

5.8. Popularity of Incentive Programs

Table 1 contains information on existing incentive programs along with the corresponding states which employ these programs based on survey responses from DOTs. Survey responses revealed that currently, 16 states had no incentive programs for consolidation of at-grade railroad crossings.

Figure 8 shows the popularity of incentive programs among survey respondents from DOTs and railroad agencies. The Y-axis represents the number of states that responded as having used a specific incentive program shown on the X-axis.

Table 1. Existing incentive programs in each state.

Incentive Programs	States
No Incentive program	ME, MA, CO, NM, ND, SD, WA, WY, ID, OR, LA, SC, AR, DE, VA, WV
Cash Incentive (CI)	NE, MS, TN, IL, MI, MN, OH, WI, NJ, NC
Nearby Crossing Improvement (NCI)	KS, NE, OK, MS, TN, IL, MN, OH, NJ, NC
Nearby Crossing Grade Separation (NCGS)	NE, TN, IL, OH, NC
Road Improvement (RI)	NE, IL, MN, OH, NJ, NC
Track Relocation (TR)	KS, MI, OH, NC

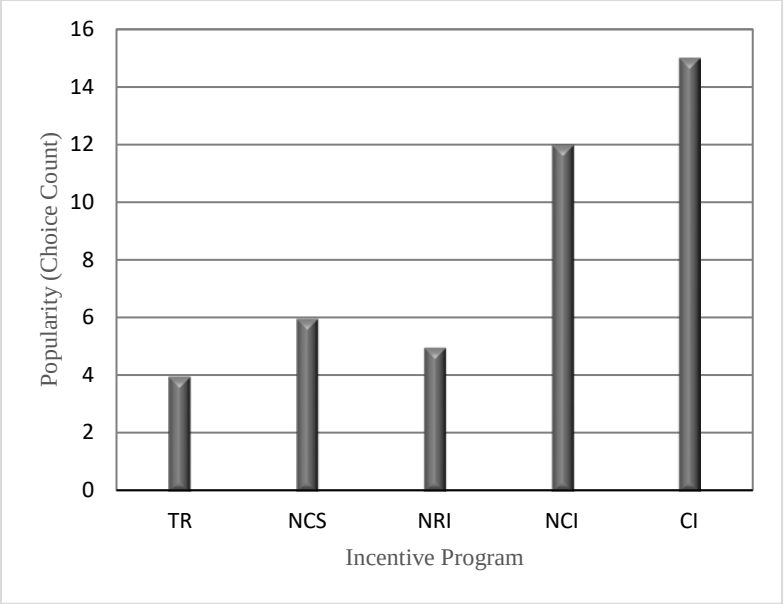

Figure 8. Popularity of incentive programs in the United States.

It can be seen that the cash incentive program was the most popular incentive program. The improvement-based programs such as nearby crossing improvement and road improvement were not quite as popular. The nearby crossing grade separation and the track relocation programs were the least popular incentive programs. Survey responses on existing incentive programs as reported by railroad agencies are documented in Table 2. Information on existing incentive programs and information on funding sources for states' crossing safety programs as found online are presented in Table 3.

Table 2. Existing incentive programs as reported by railroad agencies

Railroad Companies	Incentive Program(s)
Huntsville & Madison Railroad Authority (Alabama)	Cash Incentive
Alaska Railroad Corporation (Alaska)	No Answer
A&M Railroad (Arkansas)	No Incentive program
San Luis Central Railroad (Colorado)	No Incentive program
Colorado Public Utilities Commission (Colorado)	No Incentive program
Florida Central Railroad (Florida)	Nearby Crossing Improvement
Norfolk Southern (Georgia)	Cash Incentive, Nearby Crossing Improvement
Kankakee, Beavervill, and Southern Railroad (Illinois)	Cash Incentive, Road Improvement, Nearby Crossing Grade Separation, Nearby Crossing Improvement
Illinois Central Railroad Company (Illinois)	Cash Incentive, Finding alternative route to offset removal of an at-grade crossing
Norfolk Southern (Indiana)	Cash Incentive, Nearby Crossing Grade Separation
Delta Southern Railroad (Louisiana)	No Incentive program
Wacto Companies, LLC (Louisiana)	No Incentive program
Pinsly Railroad Company (Massachusetts)	No Incentive program
Cloquet Terminal Railroad (Minnesota)	No Incentive program
Mississippi Export Railroad (Mississippi)	An incentive program is available

Railroad Companies	Incentive Program(s)
BNSF Railway (Mississippi)	Road Improvement, Nearby Crossing Improvement
Norfolk Southern Railway (New Jersey)	No Incentive program
Santa Fe Southern Railroad (New Mexico)	No Incentive program
Western New York & Pennsylvania Railroad (New York)	No Incentive program
Ohio-Rail Corp. (Ohio)	No Incentive program
Ashland Railway Inc. (Ohio)	A combination of all incentive programs
CSX Transportation (Ohio)	Cash Incentive, Road Improvement, Nearby Crossing Improvement, Support for quiet zone establishment
Ohio Rail Development Commission (Ohio)	Cash Incentive, Road Improvement, Nearby Crossing Improvement, Track Relocation
Norfolk Southern Corporation (Ohio)	Cash Incentive, Road Improvement, Nearby Crossing Improvement, Nearby Crossing Grade Separation
Farmrail System (Oklahoma)	No Incentive program
Oregon Pacific Railroad (Oregon)	No Incentive program
West Tennessee Railroad (Tennessee)	No Incentive program
Fort Worth & Western Railroad (Texas)	Cash Incentive
Port & Pend Oreille dba Pend Oreille Valley Railroad (Washington)	No Incentive program
Watco Companies LLC (Wisconsin)	Cash Incentive

Table 3. Existing incentive programs and information on funding sources.

State	Incentives	Funding sources
AR	No Incentive programs	State funds have only been used sparingly. When state funds are used, they come from the General Improvement Fund, whose rail funding depends on a separate contingency fund.
DE	No Incentive programs	The Delaware Capital Transportation Program is a six-year investment program that is annually updated to fund infrastructure projects throughout the state. Delaware also encourages private-public partnerships.
ID	No Incentive programs	The Idaho Transportation Board allocates $250,000 annually from the State Highway Distribution account for rail safety projects. Local funding mechanisms include tax increment financing, revenue anticipation bonds, and local option taxes.
IL	Cash Incentive, Road Improvement, Nearby Crossing Grade Separation, Nearby Crossing Improvement	The Grade Crossing Protection Fund (GCPF) was created by the General Assembly to assist local jurisdictions in paying for safety improvements at crossings. Each month $3. 5 million in state motor fuel tax is transferred to the GCPF.
IN	Cash Incentive	INDOT offers incentive funding to communities who close grade crossings through the Grade Crossing Fund which provides up to $40,000 for safety improvement projects along grade crossings.
KS	Track Relocation, Nearby Crossing Improvement	The State funds a Highway-Rail Crossing Program that allocates $300,000 annually for crossing projects that are not eligible for federal aid. A 20% match is required to receive a grant.

State	Incentives	Funding sources
LA	No Incentive Program	Louisiana Transportation Trust Fund is an account into which the taxes levied on motor fuels are deposited. These funds can be used on grade crossing projects and for providing matching shares for Federal funding.
ME	No Incentive programs	The State's Grade Crossing Safety Improvement Program funds safety projects at grade crossings. The program's funding is provided through a biennial legislative appropriations process.
MI	Cash Incentive, Track Relocation	The Crossing Surface Program funds 60% of the cost of a surface improvement. The Local Grade Crossing Program allows MDOT to pay cash incentives worth $150,000 to local authorities for crossing closures.
MN	Cash Incentive, Road Improvement, Nearby Crossing Improvement	MnDOT funds the Railroad-Highway Crossing Safety Improvement Program which applies federal and state funds for different crossing projects. The Antiquated Equipment Replacement Program uses $2 million of these funds to upgrade warning systems annually.
MS	Cash Incentive, Nearby Crossing Improvement	The State's Railroad Multimodal Transportation Improvement Program funds projects that improve the safety of publicly owned railroads. The program receives 12% of the Multimodal Funds annually.
MT	Cash Incentive	-
NE	Cash Incentive, Road Improvement, Nearby Crossing Improvement, Nearby Crossing Grade Separation	The State Grade Crossing Protection Fund provides monetary incentives to local governments for crossing closures. $5,000 plus the cost of the closure will be paid for by the state and the Railroad Company.
NJ	Cash Incentive, Road Improvement, Nearby Crossing Improvement	The Rail Freight Assistance Program provides grants that cover 90% of the project cost. The rail line must continue service for at least five years following the upgrade.
NM	No Incentive programs	The State can fund rail safety improvements through Legislative Appropriations in which funds are granted through tax bond proceeds or from the General Fund.
NC	Cash Incentive, Road Improvement, Nearby Crossing Grade Separation, Nearby Crossing Improvement, Track Relocation	The Rail Industrial Access Program aids safety and construction projects by covering 50% of the costs. North Carolina Rail & Rail Crossing Safety Improvement Fund is allotted money through dividends made by the North Carolina Railroad Company.
ND	No Incentive programs	The NDDOT administers the Local Rail Freight Assistance loan fund. Loans may cover 80% of the cost with 0% - 4. 5% interest. Applicants have a 15-year payback schedule.
OK	Nearby Crossing Improvement	The State plans to dedicate $100 million to rail crossing improvements to be used over the space of the upcoming years.
OR	No Incentive programs	Oregon's Grade Crossing Protection Account is accredited $300,000 through the State Highway Fund to aid grade crossing projects. ConnectOregon improves connections between intermodal transportations. It is funded through bonds and lottery proceeds and requires a 20% match.
SC	No Incentive programs	Most rail projects are privately funded by Rail Companies with help from federal program funding, as South Carolina does not have any dedicated funding sources.

State	Incentives	Funding sources
SD	No Incentive programs	The South Dakota Railroad Trust Fund is set up to maintain and equip railroad infrastructure. This program may also be used to match Federal railroad funds.
UT	Ask for two closures to trade for the new one	The Spot Safety Improvement Program funds infrastructure projects that are expected to achieve a significant reduction in traffic fatalities and injuries. $2 million is available annually.
TN	Cash Incentive, Nearby Crossing Improvement, Nearby Crossing Improvement	The State relies on the federally funded Section 130 program to fund crossing projects and other safety improvements.
UT	Ask for two closures to trade for the new one	The Spot Safety Improvement Program funds infrastructure projects that are expected to achieve a significant reduction in traffic fatalities and injuries. $2 million is available annually.
VA	No Incentive programs	Rail Preservation Program funds projects that increase the safety and efficiency of short-lines. It is allocated $3 million annually and supports 70% of the project.
WV	No Incentive programs	The State Rail Authority receives state budget appropriations of roughly $7.7 million over five years to implement safety improvements along specific corridors.
WI	Cash Incentive	The Freight Railroad Preservation Program provides grants to local governments to improve their rail lines. These grants cover 80% of a project's cost and are paid for by bonds.
WY	No Incentive programs	WYDOT has the legislative authority to maintain a Highway Crossing Protection Account within the State Highway Fund to administer safety projects along crossings.

5.9. Effectiveness of Incentive Programs

The effectiveness of available incentive programs has been presented in Figure 9 based on utilizing the Qualtrics 'mean score for effectiveness" from the survey responses. Qualtric rates each response on a scale of 1 (least effective) – 5 (most effective) and based on the answers obtained from each survey respondent, on the effectiveness of their state's incentive programs, is able to assign an effectiveness score, which is presented in Figure 9. According to the respondents, track relocation was the most effective program followed by road improvement, nearby crossing separation, nearby crossing improvement and cash incentives.

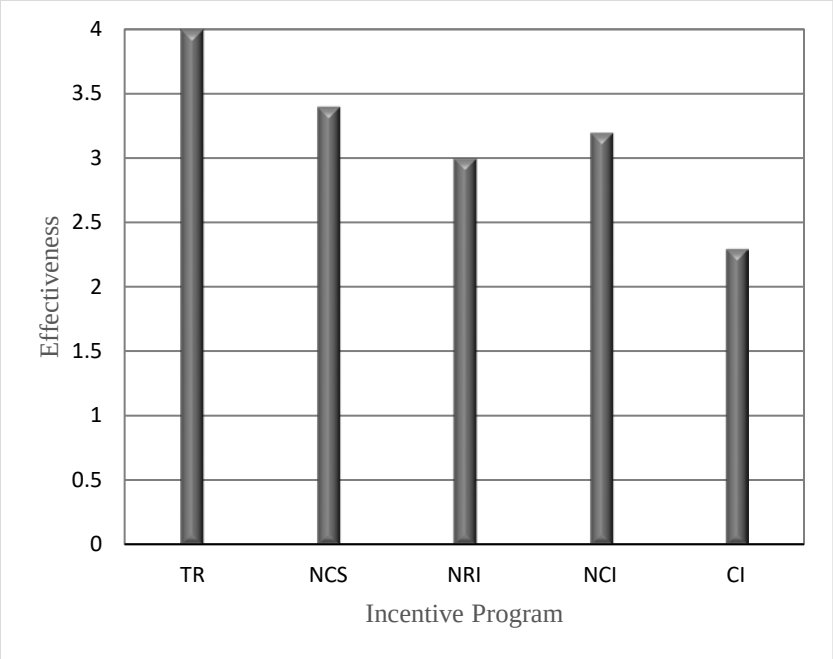

Figure 9. The average effectiveness of incentive programs.

The research team utilized another quantitative measure to assess the effectiveness of the track relocation and cash incentive programs since these showed up as the most highly and least effective programs respectively. Data in RIMS were analyzed in order to obtain the percentage of closed at-grade railroad crossings (proportion of closed to total crossings) in each of the 50 states in the US. Figure 10 shows the percentages of closed crossings – using information from RIMS - in each state as at January 2018. Further, based on a state's response, each state was grouped into either having no incentive programs (none), having cash incentive only, having cash incentive with other forms of incentives but not including track relocation, and lastly having track relocation with other forms of incentives but not including cash incentives.

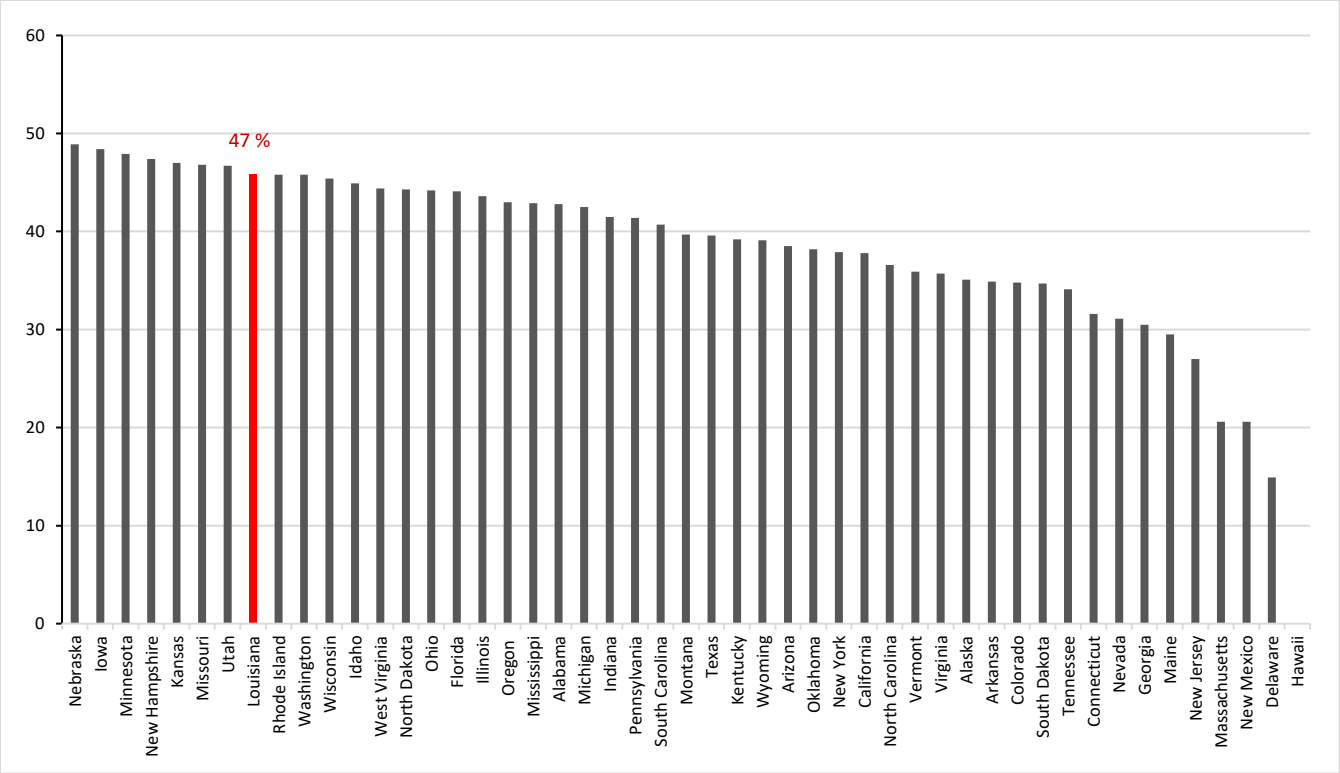

Figure 10. Percentage of closed railroad crossings for all US states.

It was necessary to have these groupings because all the states that reported having track relocations as an incentive programs also offered some other sort of incentives. Only two states offered both cash incentives and track relocation as part of their incentive programs. Since the exercise was to compare the effectiveness of each of these programs when compared to each other, these two states were removed from the analysis and subsequently, 39 out of the 42 states were analyzed and placed into groups. For each group, the average percentage of closed at-grade railroad crossings was computed and Figure 11 shows the results of this analysis. The results show that states without any incentive program had the least proportion of at-grade railroad crossing closures. Compared to other incentive program(s), the cash incentive was the least effective (39.1%). In line with the survey findings, track relocation seemed to be the most effective. Since the states that selected track relocation did not list it in isolation but added other programs to their answer choices, there was no way to find the specific impact of only track relocation. The cash incentive, in addition to other incentives, but without track relocation produced 40.8 % of crossing closures. Furthermore, track relocation combined with other incentive programs but without cash incentives produced 47% of crossing closures. This confirmed that when compared to states offering no incentive programs and cash incentive only, track relocation appeared to be a more effective incentive for at-grade railroad crossing closures.

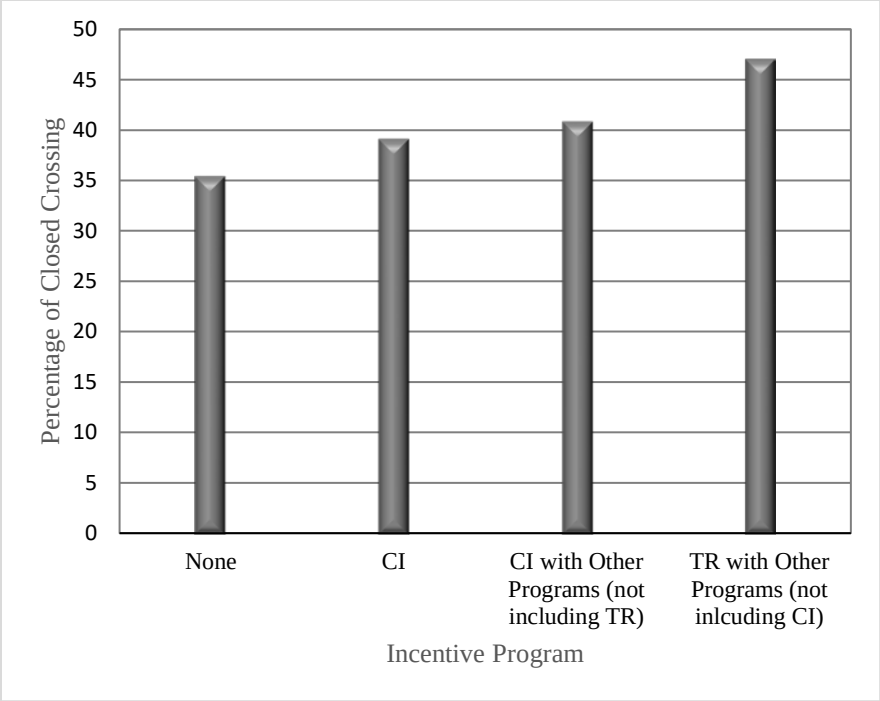

Figure 11. Percentage of closed railroad crossings by incentive program.

Watco Companies LLC in Louisiana gave an 80% effectiveness rating to improvement-based incentive programs in Louisiana even though LaDOTD provided no score as it reported Louisiana as offering no incentive programs. As at January 2018, Louisiana reported a 47% closed crossing proportion. Detailed information on the number of closed crossing in each parish in Louisiana is shown in Table 4. The Orleans parish has the most crossings (both open and closed) in Louisiana. The distribution of closed crossings between railroad agencies in Louisiana is shown in Table 5 for the period 1980 - 2018. Most of the open and closed crossings in Louisiana are under the operation of three railroad agencies, Union Pacific Railroad Company (UPRC), Kansas City Southern Railway Company (KCSRC), and Illinois Central Railroad Company (ICRC).

Table 4. The number of closed at-grade crossings by parish in Louisiana State.

Parish	# Closed Crossing (% of all closed crossings in LA)	Parish	# Closed Crossing (% of all closed crossings in LA)
Acadia	205 (4.2%)	Madison	40 (0.8%)
Allen	26 (0.5%)	Morehouse	34 (0.7%)
Ascension	19 (0.3%)	Natchitoches	49 (1%)
Assumption	197 (4%)	Orleans	300 (6.2%)
Avoyelles	155 (3.2%)	Ouachita	101 (2%)
Beauregard	25 (0.5%)	Plaquemines	45 (0.9%)
Bienville	47 (0.9%)	Pointe Coupee	37 (0.7%)
Bossier	39 (0.8%)	Rapides	109 (2.2%)
Caddo	193 (3.9%)	Red River	25 (0.5%)
Calcasieu	180 (3.7%)	Richland	77 (1.5%)

Parish	# Closed Crossing (% of all closed crossings in LA)	Parish	# Closed Crossing (% of all closed crossings in LA)
Caldwell	7 (0.1%)	Sabine	88 (1.8%)
Catahoula	46 (0.9%)	St Bernard	42 (0.8%)
Claiborne	10 (0.2%)	St Charles	37 (0.7%)
Concordia	58 (1.2%)	St James	83 (1.7%)
De Soto	18 (0.3%)	St John The Baptist	68 (1.4%)
East Baton Rouge	108 (2.2%)	St Landry	197 (4%)
East Carroll	4 (0.08%)	St Martin	198 (4.1%)
East Feliciana	44 (0.9%)	St Mary	155 (3.2%)
Evangeline	4 (0.08%)	St Tammany	108 (2.2%)
Franklin	80 (1.6%)	Tangipahoa	27 (0.5%)
Grant	30 (0.6%)	Tensas	59 (1.2%)
Iberia	172 (3.5%)	Terrebonne	90 (1.8%)
Iberville	21 (0.4%)	Union	64 (1.3%)
Jackson'	32 (0.6%)	Vermilion	63 (1.3%)
Jefferson	258 (5.3%)	Vernon	39 (0.8%)
Jefferson Davis	53 (1%)	Washington	86 (1.7%)
La Salle	24 (0.4%)	Webster	39 (0.8%)
Lafayette	112 (2.3%)	West Baton Rouge	57 (1.1%)
Lafourche	191 (3.9%)	West Feliciana	60 (1.2%)
Lincoln	42 (0.8%)	Winn	43 (0.8%)
Livingston	6 (0.1%)		

Table 5. The number of closed and open at-grade crossing of each Louisiana railroad agency.

Primary Operator	# Open (%)	# Closed (%)
Union Pacific Railroad Company (UP)	1395 (24.8%)	2114 (43.92%)
Kansas City Southern Railway Company (KCS)	1353 (24.05%)	487 (10.12%)
Illinois Central Railroad Company (IC)	629 (11.182%)	510 (10.6%)
BNSF Railway Company (BNSF)	384 (6.83%)	162 (3.36%)
New Orleans & Gulf Coast Railway Company Inc. (NOGC)	276 (4.91%)	57 (1.2%)
Norfolk Southern Railway Company (NS)	276 (4.91%)	80 (1.7%)
New Orleans Union Passenger Terminal (NOUP)	235 (4.2%)	82 (1.7%)
Louisiana Southern (LAS)	223 (4%)	23 (0.47%)
Acadiana Railway Company (AKDN)	172 (3.06%)	78 (1.62%)
LOUISIANA DELTA RAILROAD (LDRR)	165 (2.93%)	402 (8.35%)
NOLC (NOLC)	95 (1.69%)	15 (0.31%)
Delta Southern Railroad Company (DSRR)	82 (1.46%)	39 (0.81%)
Arkansas Louisiana & Mississippi Railroad Company (ALM)	79 (1.4%)	9 (0.19%)
Southern Pacific Transportation Company (SP)	59 (1.05%)	3 (0.06%)
Louisiana & North West Railroad Company (LNW)	48 (0.85%)	12 (0.25%)
North Louisiana & Arkansas Railroad (NLA)	43 (0.76%)	2 (0.04%)
Geaux Geaux Railroad, LLC (GOGR)	38 (0.67%)	2 (0.04%)
Southern Railway Company (NSX) (SOU)	37 (0.66%)	3 (0.06%)
CSX Transportation (CSX)	26 (0.46%)	42 (0.87%)
Baton Rouge Southern Railroad (BRS)	8 (0.14%)	0 (0%)
New Orleans Public Belt Railroad (NOPB)	2 (0.04%)	0 (0%)
Arkansas Midland Railroad Company, INC. (AKMD)	0	1 (0.02%)
Atchison, Topeka & Santa Fe Railway Company (ATSF)	0	17 (0.35%)
Central Louisiana & Gulf Railroad Company [CLGR] (CLGR)	0	1 (0.02%)
Chicago, Rock Island And Pacific Railroad (RI)	0	63 (1.3%)
Columbus And Greenville Railway Company, Co (CLG)	0	1 (0.02%)
Gloster Southern Railroad (GLSR)	0	27 (0.56%)
Gulf States Power (GSP)'	0	1 (0.02%)
Illinois Central Gulf Railroad Company (ICG)	0	121 (2.5%)
Louisiana & Arkansas Railway Company (LA)	0	112 (2.33%)
Louisiana Midland Railway Company (LOAM)	0	60 (1.25%)
Louisiana Southern Railway Company (LSO)	0	4 (0.08%)
Midsouth Railroad Corporation (use Code KCS) (MSRC)	0	65 (1.35%)
Missouri Pacific Railroad Company (MP)	0	1 (0.02%)
North Louisiana & Gulf Railroad Company (NLG)	0	2 (0.04%)
PORT RAIL INC (PTRI)	0	12 (0.25%)
St. Louis Southwestern Railway Cc. (SSW)	0	185 (3.84%)
Timberrock Railroad Company, Inc. (TIBR)	0	9 (0.18%)
Uachita Railroad (OUCH)	0	9 (0.18%)

5.10. Potential New Incentive Programs

In the online survey, the research team asked respondents to suggest potential programs that could reduce the number of highway-rail incidents. Out of 55 respondents to this particular question, 27.3% suggested the establishment of laws to assist closure of public and private crossings. Raising awareness of at-grade railroad crossing safety issues was a potential program that was advocated for by 23.6% of respondents. Finding resources to increase the existing cash incentive offered was the least popular potential program for crossing closures (16.4%). Another potential program was designing a holistic consolidation model considering other aspects beyond safety, e.g., social factors, environmental effects, and economical condition (21.8% of respondents supported this program). Respondents suggested incorporating grade separation into the crossing consolidation programs.

A respondent from Michigan DOT (MDOT) noted that some of these "new" programs had already been implemented in Michigan and was not optimistic about these potential programs. He mentioned that there was a law which allowed any crossing to be closed and in doing so, MDOT officials never considered what was best for the community. However, respondents from Louisiana specifically suggested that laws should be established to assist closure of both public and private crossings and that public awareness of highway-rail grade crossing safety issues should be raised.

5.11. Reported Additional Existing Incentive Programs

In designing the survey, the research team identified common existing incentive programs and asked respondents to confirm which ones their state or agencies offered and also to comment on their effectiveness. In addition, respondents were to report any additional existing incentives that were not included on the survey. Three additional existing incentive programs were reported by respondents from Utah, Ohio, and Illinois. They were: closing two crossings in exchange for a new crossing, supporting quiet zone establishment, and considering alternate routes to offset the removal of grade crossings. These are further explained below.

5.11.1. Two Closures in Exchange for a New Crossing

Crossings are closed for safety reasons, usually when consolidation programs take effect. Although this may not be considered to be an incentive program for closure, the Utah Department of Transportation (UDOT) generally asks for two crossing closures in exchange for a new crossing when a request for a new crossing is received. Before any closure, however, UDOT temporary closes a crossing to analyze the impact on surrounding communities. If it is determined that two crossing closures would not be possible, significant safety improvements must be applied to other crossings to enhance safety *(22)*. The success of this program is tied with its effect on the accessibility of streets and traffic flow in the neighborhood.

5.11.2. Quiet Zone Establishment

FRA established nationwide standards regarding when trains may sound their horns at highway-rail crossings. The rule states that all horns, regardless of the sounding pattern, must be sounded at least 15 seconds, and no more than 20 seconds, in advance of all highway-rail crossings with volume ranging from 96 decibels to 110 decibels *(14)*. However, there are opportunities to reduce noise created by train horns outside of the FRA mandated areas through

the establishment of quiet zones *(23)*. In order to achieve this, other highway-rail grade crossing safety improvements should be provided to mitigate the risk created when train horns are not used. Examples of suggested improvements are installing four quadrant gates and active warning devices. There are 570 new quiet zones located across the US states which were established from June 2005 to June 2017. Three of these new quiet zones are located in Louisiana *(23)*. The staff of Ohio Department of Transportation used the establishment of quiet zones and the improvement at nearby crossings as incentives to encourage residents and crossing owners to support at-grade railroad crossing closures.

5.11.2. Alternate Routes

The major concern of residents who are opposed to closure of crossings is the fear of reduction in accessibility. This program works at the crossings where local conditions indicate there are legitimate objections against closure. It provides flexibility for a community that supports closures as long as certain local concerns such as accessibility reduction, out-of-the-way distance, traffic jams, and noise associated with train horns are addressed. Illinois Central Railroad Company reported using this additional incentive to encourage closures of redundant at-grade railroad crossings.

5.12. Identified Potential New Incentive Programs

The research team identified potential new incentive programs that could offer promise in reducing the number of at-grade railroad crossings, specifically, for the state of Louisiana. This was achieved through a combination of literature search, additional research using Louisiana-specific data, and an additional survey, particularly targeted at Louisiana State railroad representatives consisting of either railroad safety or railroad industry professionals. Three such potential programs were identified that targeted elements specific to Louisiana. These are incentives based on crime rate reduction, increasing the greenness of a vicinity, and using tools – such as consolidation models – to justify closure or consolidation of at-grade railroad crossings. Each of these are further explained below.

5.12.1. Crime Rate Reduction Programs

This incentive program is crime rate reduction in areas surrounding a closed crossing. It is a well-established fact that crime rates vary among neighborhoods *(24)*. According to the Pareto Principle (also known as 80:20 rule) *(25)*, crime rates tend to be correlated with specific places and things. This establishes that there is strong connection between crime and place so in order to reduce crime rates in an area, focus must be redirected from individual criminals to crime locations. The relation between crime and place is supported by three theories: rational choice theory, routine activity theory, and crime pattern theory. Rational choice presents the basic rationale for defining place as important. Routine activity theory explains the occurrence of crime events as several circumstances coming together. Crime Pattern theory combines the previous theories to help explain the distribution of crime across locations *(26)*.

Crime in Louisiana, is not randomly distributed, but is highly dependent on the spatial characteristics of an area. The theory being postulated is that since closure or consolidation of grade crossings would alter accessibility of a location, so would crime rates of these locations. Since crime rates and railroad crossings numbers are high in Louisiana, further preliminary

research was conducted in this study to identify the impact that a crossing closure may have, if any, on crime rate.

According to Crime Prevention Through Environmental Design (CPTED) principles, closures of at-grade railroad crossings may reduce crime rate more drastically than overpass and underpass crossings *(27)*. Generally, there is a relationship between street access and crime rate. Clarke *(25)* and Poyner *(28)* state that any physical change, such as temporary or permanent street closures, changes crime rate in a neighborhood since travel is decreased, providing residents with a safer area. Also, escape routes are limited for would-be offenders, as criminals, who are outsiders, are less likely to become familiar with the place, and drive-by shootings are prevented *(25, 28)*.

To get a bigger picture of the crime distribution around railroad crossings, a spatial distribution analysis was done on East Baton Rouge crime from 2011 to 2016. The kernel density analysis on CrimeStat 4.02 was run so as to obtain the crime density in the area. ArcGIS 10.4 was also used to visualize the crime density distribution on a map since CrimeStat software did not show spatial data. Figure 12 and Figure 13 show crime density in East Baton Rouge Parish in 2011 and 2016, respectively. On these maps the red points illustrate the closed crossings and the black ones show the open ones. We used crime density around crossing neighborhoods before and after closure of crossings. Figure 12 indicates the crime density in Baton Rouge, LA in 2011 and Figure 13 shows the crime density in 2016. The aim was to find the amount of changes in density around the closed crossing from 2011 to 2016. The standard deviation shows the extent of crime density deviation from the mean density. The darker the color in blue, the more increase in crime density after 5 years. The darker the yellowish cells, the more decrease in crime density in an area. To calculate the crime changes around closed and also open crossings, we used the average of 4 nearby cells around each crossing.

Generally speaking, the crime density was greatly decreased by 2016, and it can be seen that the density is lower around closed crossings than open ones for both years. This seems to support the theory that locations with closed crossings generally resulted in lower crime rates. However, upon closer examination, it was realized that some closed crossings showed high crime densities (e.g. the crossing at Choctow Dr., Baton Rouge, LA). The research team took a field trip to this location and noticed that the siding tracks at the closed crossings had been removed (Figure 14). This situation indicated that accessibility was improved in the area by removing the siding tracks, thereby increasing crime rate instead. In effect, where closure increased accessibility, crime rates are likely to increase.

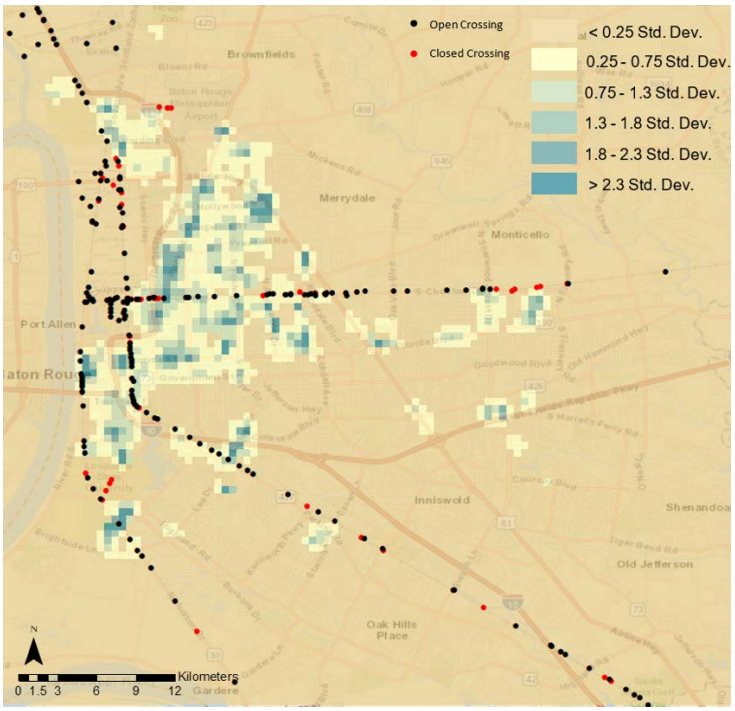

Figure 12. East Baton Rouge Parish crime density in 2011.

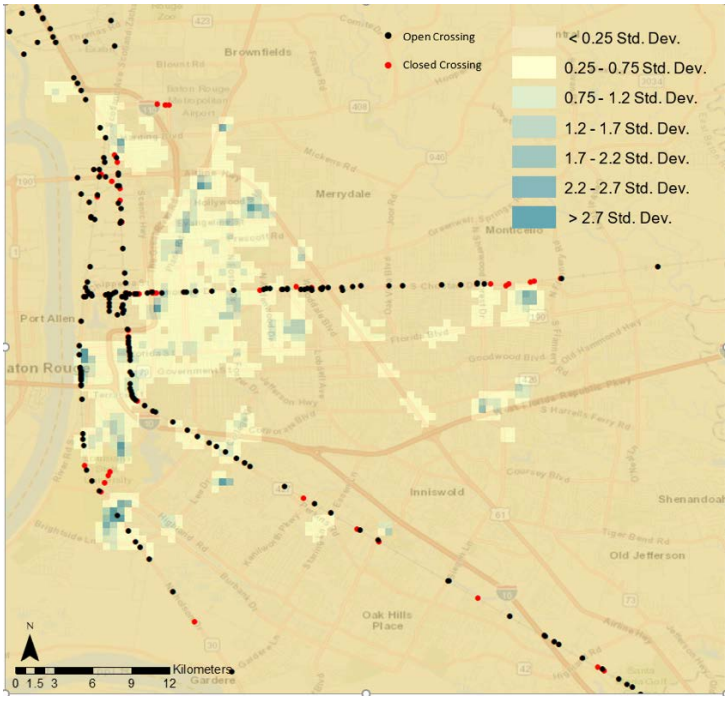

Figure 13. East Baton Rouge Parish crime density in 2016.

Choctaw Dr. near Airline Hwy. (Closed on Feb 24 2016)

Choctaw Dr. and Phlox Ave. (Closed on Nov 14 2016)

Rosen Wald Rd. near Veteran Memorial Blvd. (Closed on Dec 7 2015)

Choctaw Dr. and18th St. (Closed on Aug 2 2016)

Figure 14. Closed crossings in Baton Rouge, LA where siding tracks were removed.

According to CPTED, people generally believe that different surveillance factors positively affect the safety of a neighborhood *(28)*. Some of the surveillance factors are lighting, and access control factors such as road closures/street changes. So, we can therefore infer that the consolidation of highway-rail grade crossings affects the crime pattern in a neighborhood and reduces the number of crime incidents in general. However, some may be opposed to this assumption since the results of CPTED projects are just observation-based *(27)*.

The study of crime change after any physical change is a micro-level question that needs to take other factors into consideration, such as police patrol, increasing illumination, crime prevention through environmental design, supportive residents, and security guards. Generally, a decline in the number of crime incidents after crossing closures is expected, due to reduced accessibility.

In the Louisiana-specific survey, respondents were asked whether they supported closure/consolidation of highway-rail grade crossings as a means of reducing the non-traffic related crime rate in their jurisdiction. Examples of non-traffic related crime were given to be robbery, vehicle burglary, and assault. Out of the 13 responses, eight respondents supported the view that consolidation programs reduced crime rates, two of them expressed opposite sentiments and three remained undecided. The survey results informed the research team's

decision to include crime rate reduction as an incentive program, especially in Louisiana. However, additional analysis needs to be done in this area to determine whether crime rates are reduced as a result of closure of crossings in Louisiana.

5.12.2. Greenness Improvement Programs

Another incentive program that was explored in this research was the relationship between land cover and closed at-grade railroad crossings in an affected neighborhood. It is postulated that communities will be more welcoming of closures if it can be proven that it increases the greenness of the community. The team made efforts to identify land cover changes around highway-rail grade crossing which had been closed. Also, the research team tried to find the land cover type associated with the greatest number of closed crossings.

The city of Baton Rouge, the capital of Louisiana closed 108 at-grade railroad crossings from 1980 to 2017. The number of crossings that were closed for each year is shown in Table 6. It can be seen that most of the crossings in Baton Rouge were closed in 2011. Due to the amount of data available in 2011, the research group analyzed the crossings closed in 2011 in order to investigate the relationship land cover had with closed crossings.

Table 6. The number of closed grade crossing in Baton Rouge from 1980 – 2017.

Year	# Closed Crossing	Year	# Closed Crossing
2017	2	1995	1
2016	8	1994	4
2015	4	1992	15
2012	1	1990	1
2011	28	1989	1
2010	6	1987	14
2007	1	1985	1
2004	18	1982	1
1996	1	1980	1

Remote sensing methods were required to obtain information about land cover. Various methods can be used for remote sensing image classification including supervised and unsupervised classification. Supervised classification applies a number of training sites whose classes are already defined and connected to test sites. The accuracy of this approach highly depends on how the representative samples are defined. The more accurate the classification of samples sets, the more accurate the classification. The schematic approach of supervised classification, improves the accuracy of classification by recreating the training test in each step. In unsupervised classification on the other hand, the number of required classifications is defined to put each pixel in the most related clusters. This approach puts together pixels which have more similarities than others. This similarity can be measured based on specific properties. In this research, pixel color is used to differentiate between clusters of land covers. The accuracy of classification can also be improved by changing the number of required clusters. Since the accuracy of supervised classification is far greater than the accuracy of unsupervised classification, a supervised classification was applied in this study to detect various classifications of land covers using remote sensing data.

In supervised classification, training clusters are defined first. Using the Landsat 8 image that was taken in December 2016, a signature file was developed. The developed clusters defined different land covers namely Shrubland, Industrial, Forest, Residential, Water, Agricultural, Soil, and Grassland. The maximum likelihood classifier is the algorithm ERDAS IMAGIN 2015 software uses to identify each defined class.

Remote sensing results from analyzing the two satellite images (Figure 15 is a Landsat 5 image taken in December 2010, and Figure 16 is a Landsat 8 image taken in December 2016) for land cover detection over six years, showed that 75% of the land cover around closed crossings changed over six years. Most of the crossing closures happened in industrial neighborhoods in Baton Rouge. Focusing more on the type of closures, the research team noticed that most of the closed crossings in these industrial areas were done by removing siding tracks. Generally, most of the changes that occurred were related to the transformation of industrial land cover to residential ones. Researchers believe that as the population of the city increased over the years, urban planners of the city relocated industrial areas away from the growing residential districts. The land cover changes around the 28 closed highway-rail grade crossings over six years is shown in Table 7.

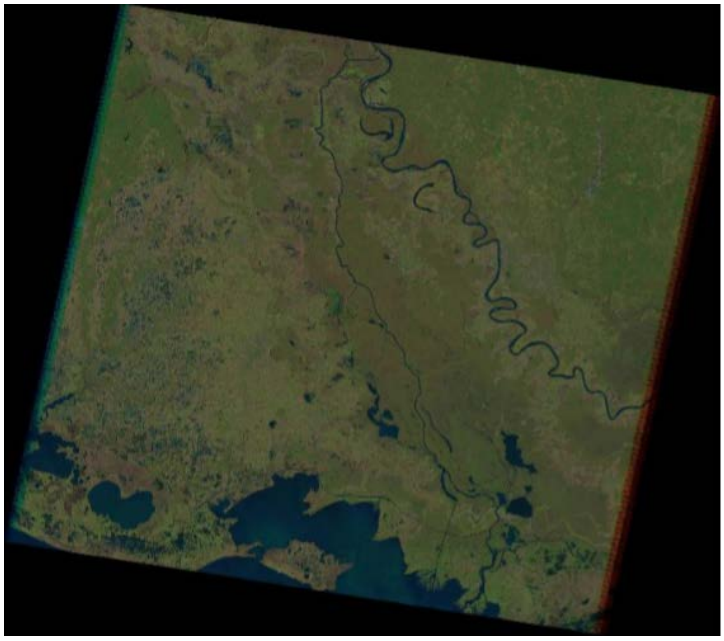

Figure 15. Landsat 5 image, Baton Rouge, LA (Dec 1, 2010).

Figure 16. Landsat 8 image, Baton Rouge, LA (Dec 1, 2016).

Table 7. The number of closed crossings in each land cover.

Land Cover	Number of Closed Crossing in Dec 2010	Number of Closed Crossing in Dec 2016
Forest	4	6
Soil	2	2
Grassland	0	2
Agriculture	1	0
Residential	2	10
Shrub land	1	2
Industrial	18	6
Water	0	0

The results show an improvement in the greenness of the city due to the increase in the area of grassland, shrub land, and forest land cover. Greenness improvement can therefore be considered as one of the incentives for closure. However, it is worth mentioning that this analysis has to be done at other locations using more data to ensure that the results will be applicable in other cities beside Baton Rouge.

5.12.3. Justification of Closures/Consolidation Using Mathematical Models

Consolidation programs usually find the most dangerous and/or redundant (low-used) crossings in a neighborhood in order to close them. There are various factors (for instance, crossing engineering design, street structural design, warning devices, environmental, and weather conditions) that are considered when identifying such crossings. A crossing's use and

traffic flow is related to the population of the neighborhood, street structural design, and also, the existing land use. The urban planning of a city, land use management, infrastructure systems, accessibility, community cohesion, environmental management, crisis management, and economical condition of various facilities may be affected by unwarranted crossing closures.

Any mathematical model to be used as a tool to justify closure or consolidation of crossings must consider all the factors listed above. Because the factors are many, to increase the effectiveness of such a tool, care must be taken to use only the most important factors that actually contribute to the effectiveness of such closures. Agencies have been able to choose these factors based on expert knowledge, although it is now possible to do this through Machine Learning tools. For this study, the research team identified the important factors to be used for such a mathematical model through both ways – using expert knowledge through the Louisiana-specific survey, and using a Machine Learning tool, namely eXtreme Gradient Boosting (XGB). The research team stopped short of developing the actual mathematical model as this is beyond the scope of this study. The sections below further elaborate on these efforts.

Expert Knowledge from Louisiana-Specific Survey: This section describes how the survey responses from Louisiana railroad representatives were used to develop a list of the most important factors to be considered for the development of any crossing consolidation/ closure mathematical model. An online literature search combined with querying the variables in RIMS and FRA database revealed that the factors agencies tend to use in developing mathematical models included: Intersecting Roadway Within 500 ft., AADT, Estimated Percent Trucks, Number of School Bus/ EMS Passing on a Day, Flashing lights/ Active alarms, Signs/ Passive alarms, Type of Land Use, Road Function/ Number of Lanes, Smallest Angle of Road and Rail, Bells / Quiet Zone, Crossing Type (private/ public), Signs/ Passive alarms, Development (urban/ rural), Typical Train Speed, Roadway Pavement Condition (paved/not paved), Typical Vehicle Speed, Crossing Purpose (pathway/ highway), Crossing Surface, Disability and Bike Access, Day Through Train Movement, Low Ground Clearance Signs, Night Through Train Movement, Location Specific Characteristic (flood/ snow), Crossbuck Assemblies, Sight Distance, Roadway Gate Arms, Crime Pattern, and Crossing Illumination.

The railroad safety representatives of Louisiana were asked to select and rank at least three factors they consider most important and at least three other factors they consider least important. Higher ranked numbers were considered more important and least ranked numbers were considered less important. Average scores were computed for each factor and the results have been presented as shown in Figure 17 below. The survey response was approximately 69% (18 responded out of 26).

The results show that factors such as AADT, development (urban or rural area), sight distance (visibility at the crossing), low ground clearance sign, number of school bus/EMS crossings per day, road function (which defines the number of lanes), smallest angle of road and rail, day/night through movement, active alarms, and typical train speed were considered highly important. However, respondents placed low importance on other factors such as crossing

surface, crossing illumination, land use, bells, pavement condition, crime pattern, and the specific physical condition of the place (flood, ice, etc.).

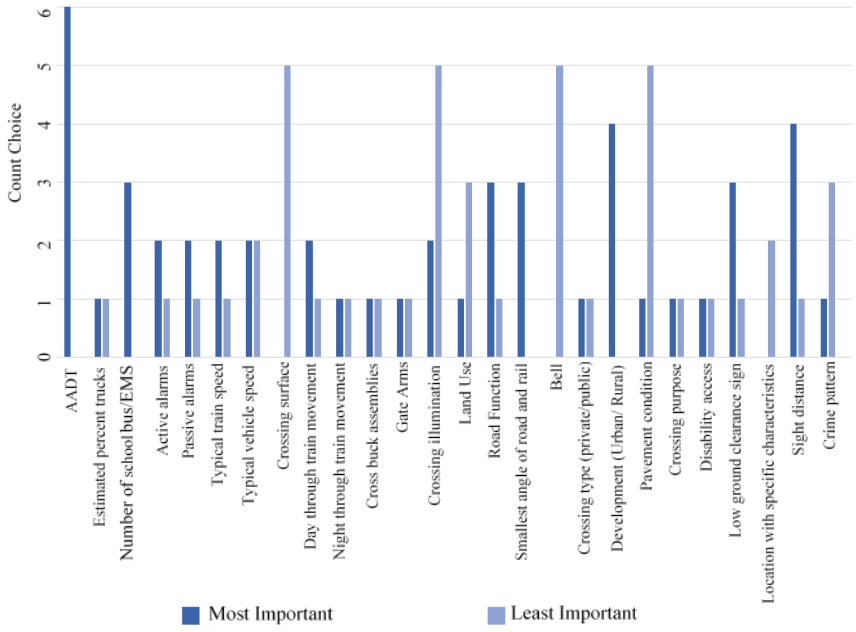

Figure 17. Important factors identified by Louisiana railroad representatives.

These results, while not representative of the entire state because of the limited responses, reflect the actual importance placed on each factor by local expert judgement. In the development of a consolidation/closure mathematical model, it will be prudent to limit the variables to only the factors that are considered important. The complete survey questions and responses have been included in the Appendix.

Identification of Important Factors Through Machine Learning Tools: Machine Learning tools can be used to develop rating formulae to identify which crossing(s) to close and which crossing(s) to keep open *(13)*. There are several rating formulae for crossings which are used to calculate the importance of each crossing, considering various crossing characteristics. The most well-known of them are as follows:

- The formula published by Russell and Mutabazi *(29)* using 8 factors (road type, Average Daily Traffic (ADT), accessibility, obstruction, crossing angle, approach horizontal alignment, approach vertical alignment, and rideability) *(13, 29)*.
- The rating formula used for prioritization of federal crossing upgrade funds based on average daily traffic, 24-hour train counts, train speed, existing crossing protection (ranges from 0.10 for crossings with gates to 1.00 for crossings with only crossbucks or other protection), and the number of crashes at the crossing in the past five years, which was also formulated in 1998 *(13)*.
- The California Public Utilities Commission calculated the priority of crossings for closure based on annual average daily traffic, train traffic, light rail train traffic (if

applicable), accident history at the crossing, a special conditions factor, and the project cost share to be allocated from the grade separation fund in 2013.

- In 2015, Iowa University used several factors to produce a rating formula. They were travel distance, AADT, truck AADT, proximity to schools, and proximity to emergency services (EMS) providers, alternate route crash rate, and primary or farm-to-market road system status. Using a weight matrix, every two factors were weighted for both urban and rural areas to create two linear formulae and calculate crossing score.

Previous works rated each crossing in a simple way considering very limited number of variables and linear relationships. To fill this gap, the research team included about 40 variables for its model. It is expected that the Machine Learning tool will be able to identify the most important variables, based on some prescribed criteria that will be stipulated by the research team. As earlier noted, this study only identifies the important factors but fall short in developing the mathematical model. The sections below detail the research team's attempt in using the Machine Learning tool to identify the most important variables.

XGB Model Definition: Previously, multi-criteria assessments (MCA) based on experts' judgement were used to determine the weighting to be applied to each factor in the consolidation model. Another way to identify the importance of factors without depending on experts' knowledge is the use of data mining and machine learning frameworks. Machine learning trains the available crossing data in order to come up with a holistic model. Among all machine learning algorithms, eXtreme Gradient Boosting (XGB) is claimed to be a highly accurate and easily understandable decision tree method so the research team selected it for the preliminary consolidation model. XGB is a supervised algorithm that is based on the original model of gradient boosted trees presented in Friedman *(30)*. Supervised algorithms need sufficient training data to retrieve information, then the test data is used on the prediction model to calculate an outcome. The model can be defined using a formula depending on whether the problem is a regression or classification model. To estimate how well the model is working, an objective function (L) is also needed. It contains two terms: loss function (*l*) and regularization term (Ω) *(31)*.

$$L(\emptyset) = l(\emptyset) + \Omega(f) \qquad [1]$$

Loss function measures the difference between the prediction and target function and the most common loss function is the mean square error. The regularization term, however, is required to avoid unnecessary complexity and overfitting *(32)*.

$$\Omega(f) = \gamma t + \frac{1}{2}\lambda \sum_{j=1}^{t} {w_j}^2 \qquad [2]$$

In equation 2, t is the total number of leaves, Wj 2 is the weight score on the j^{th} leaf, γ is the minimum split loss reduction, and λ is the regularization parameter. λ defines the complexity of the parameters such that the higher is it, the higher the shrinkage of parameters towards 0 *(32)*. A detailed analytical overview for the XGB algorithm training can be found in *(31, 32)*.

Data Acquisition: To improve the accuracy of the consolidation prediction models, the research group used 40 variables related to highway-rail grade crossings out of the 152 variables in RIMS and FRA database. Trees in the Gradient Boosting (GB) algorithms were

grown sequentially to improve the robustness of the algorithm against overlapping class distributions by optimizing an arbitrary differentiable loss function using Gradient Descent method. Sequential improvement of the algorithm enhances its accuracy due to the learning rate that shrinks the contribution of each successive tree. The model was developed to detect open crossings that were suitable for closure based on defined factors. To achieve this, 18,485 highway-rail grade crossings were selected from 18 states including Alabama, Arkansas, California, Florida, Georgia, Illinois, Indiana, Michigan, Minnesota, Mississippi, Missouri, North Dakota, Ohio, Oklahoma, Texas, Washington, Wisconsin, and Louisiana *(1)*.

The whole data set contained 12,741 closed crossings, 424 newly open crossings, and 5,320 open crossings. After preprocessing the data, all of the records had completed attributes and no missing data was exist within the dataset. Assuming that the already closed crossings and the newly open crossings were the best options for crossing closures and crossing openings respectively, the proposed model aimed to classify open crossings into two categories (closed or open). By doing so, the best crossing candidates for closure were defined.

Model Performance Measures: The area under the curve (AUC) metric was used to evaluate model accuracy. The curve refers to the Receiver Operating Characteristics (ROC) curve. There is always a trade-off between specificity (how correctly negative events are classified) and sensitivity (how correctly positive events are classified) in most classifiers. The perfect ROC curve has an AUC of 1 *(33)*. The sensitivity and accuracy values are used as the performance measures for the testing data (Equation 3 and Equation 4).

$$Sensitivity = \frac{a}{A} \quad [3]$$

$$Accuracy = \frac{a+b}{A+B} \quad [4]$$

Where a is the number of correctly classified closed crossings, b is the number of correctly classified newly open crossings, A is the total number of actually closed crossings, and B is the total number of actually open crossings in the dataset.

The available data was highly imbalanced (a large number of closed crossings compared to the newly opened ones) which could result in classification error. To avoid classification error sampling was required. In order to handle imbalanced classes, two approaches could be implemented: downsampling the major class or upsampling the minor class of data set *(34)*. In this study upsampling was used while training the data. The upsampling process randomly unsampled the available classes to set an approximately uniform distribution before the classification step began in each iteration *(35)*.

After handling class imbalance, the actual data was divided into two parts: training and testing. The 70% of data was selected to train the model and the rest of it was used to test the trained model. The data set used for analysis had 40 different variables for the development of a tree-based model. Prior to model training, hyper-parameters including the maximum tree depth (D), a subset of features (S), a number of trees (T), and a learning rate (L) were defined. Depending on the type of tree algorithm, one or more hyper-parameters should be defined first.

Unlike most machine learning models that are difficult to interpret, the XGB reports the relative importance of all variables in the model. This provides better insight and understanding of the model when the extent to which each factor affects model is known. The normalized relative importance of the variables is shown in Table 9. The higher the value, the more important the variable is. These values provide a technical guidance for developing a simplified model without compromising the detection accuracy. According to Table 8, the most important variable in the model is "intersecting roadway within 500 ft.," followed by "estimated percent trucks," both contributing 18.1% and 9.34%, respectively to build the XGB model. The significant contribution of intersecting roadway within 500 ft., was expected since it was intuitive that the higher the number of intersections around the crossing, the higher the probability of an accident occurring near the crossing. This also increases the chance of that crossing to be either separated, upgraded, or closed. Moreover, the high importance of truck percentage indicates the importance of the crossing to transportation which makes consolidation more difficult. This finding is consistent with previous research *(15)* as well as the survey responses from the Louisiana railroad representatives.

Model Training: To be able to determine whether the XGB model performed well, two additional Machine Learning algorithms were used to analyze the testing dataset and the results compared. These are Decision Tree (DT) and Random Forest (RF). In a standard Decision Tree, each node is selected based on the best split among other values *(36, 37)*. To select a certain variable to split a node, the information gained by branching on that node is calculated *(36)*. The gain value is measured by the changes in entropy due to splitting this node into two sub-nodes. The entropy is an indicator that computes the relative frequency of classes to measure the impurity of the classification on the sub-nodes. The decision tree prediction model only needs the D parameter to be defined. It denotes the number of successive nodes/splits in the tree. The more the D the higher the accuracy of the tree, however it may also cause overfitting. Random Forest selects each node based on the best split values among a subset of randomly selected values rather than all values. The RF algorithms propose additional random layers to bagging and changes the structure of classification or regression trees *(36)*. Before training a model using RF, a subset of features (S) should be defined as well as the number of trees (T). There is no need to define the tree depth since for each tree the maximum possible depth of trees is considered. In this study the S variable ranges from 1 to 40 and includes all the variables in the dataset. In relation to T values, the more the number of trees the higher the accuracy of the model, however since the computational cost is increased, an optimal value is always selected by RF. The results of these algorithms are demonstrated in Table 9.

Finally, the XGB requires tuning of D, and T, as well as the extra regularization of parameters L, γ and λ. The γ and λ are assigned a value of 1 while tuning the hyper-parameters. The role of L value is to avoid overfitting by decreasing the contribution of each successive tree ($0 < L < 1$). Like the RF algorithm, the accuracy of model is increased by increasing T while it may also cause overfitting problem. To tune these hyper-parameters for different algorithms, a combination of ten-fold and grid search techniques is applied. Grid search, as an exhaustive search, works to define the optimal combination of hyper-parameter values. The different parameters spaces are defined as $D \in [1, 2, \ldots, 10]$, $S \in [10\%, 20\%, 25\%, 30\%, 50\%, 75\%, 100\%]$, $T \in [1, 2, \ldots, 4000]$, and $L \in [0.0001, 0.0005, 0.001, 0.005, 0.008, 0.009, 0.01, 0.02,$

0.03, 0.05, 0.1, 0.5]. While the learning rate values are commonly assumed to fall between 0. 1 and 0. 3, this study implemented a wider range of learning rate values due to the large number of trees (1-2000). The learning rate values and the varying step size were determined based on a sensitivity analysis and preliminary investigation using different values. The best combination for hype-parameters was L=0.03, D=10, S=20%, T=1000.

The grid search is guided by a ten-fold cross validation technique in which the data is divided into 10 subsets. To perform the ten-fold cross validation, the 70% training/validation dataset is divided into 10 subsets. Then, model training is performed using nine subsets and validation is done using the remaining subset. This is repeated 10 times by changing the validation subset. For each trial, the AUC measure is obtained, and the average AUC value is then obtained for the ten trials to evaluate the model performance.

To evaluate the models' performance, the testing dataset is used to calculate the sensitivity and accuracy measures. Table 8 summarizes the results for the model sensitivity and accuracy as well as the overall confusion matrices obtained for each of the applied algorithms.

Table 8. The performance of the developed models on the testing dataset.

DT(J48)			
	Predicted Class		
True Class	Closed	Newly Opened	
Closed	3821	15	Accuracy 0.98
Newly Opened	35	78	Sensitivity 0.996
ROC	0.861		Correctly classified: 98.73%

(a)

RF			
	Predicted Class		
True Class	Closed	Newly Opened	
Closed	3835	1	Accuracy 0.99
Newly Opened	35	78	Sensitivity 0.999
ROC	0.988		Correctly classified: 99.01%

(b)

XGB			
	Predicted Class		
True Class	Closed	Newly Opened	
Closed	3821	28	Accuracy 0.991
Newly Opened	7	94	Sensitivity 0.996 %
ROC	0.967		Correctly classified: 99.13%

(c)

The size of the pruned tree was 55 and the number of leaves obtained was 32. When using random forest, different subsets of variables should be tested to select the optimal subset. Different parameters were defined as S ϵ [20%, 50%, 80%, 100%] and the iteration size (size

of tree) was 100. The table values are consistent with the validation results as they confirm that the XGB algorithm outperforms all other algorithms with a prediction accuracy of 99.1% and sensitivity of 99.6%. The RF algorithm comes second in performance followed by the DT algorithm. Thus, the XGB tool used for the identification of important variables was appropriate.

The Importance of Variables: Unlike most machine learning models that are difficult to interpret, XGB reports the relative importance of all variables to the model. This provides better insights and understanding of the model knowing the extent to which each factor affects model. The normalized relative importance of the variables is shown in Table 9. Furthermore, XGB machine learning algorithm was used to identify the significance of variables which have been listed in Table 9. A description of each variable can be found on the FRA website.

Based on XGB results, the most important variables in the model are intersecting roadway within 500 ft., estimated percent trucks, AADT, typical train speed, average number of school bus, total switching trains, total count of flashing light, day thru train movements, and total train. The significant contribution of intersecting roadway within 500 ft., was expected since the higher the number of intersections around the crossing, the higher the probability of accident near the crossing, so the higher the chance of that crossing to be either separated, upgraded, or closed. Moreover, the high importance level of truck percentage indicates the importance of the crossing for transportation, which makes consolidation agreement between railroad agency and crossing owner more difficult. This the experts' judgment which was explained in previous sections.

Table 9. Importance weighting of variables using data mining.

Factors or Variables	Importance
Intersecting Roadway Within 500ft.	18.10%
Estimated Percent Trucks	9.34%
AADT	7.76%
Typical Minimum Speed.	5.55%
Typical Maximum Speed	5.12%
Number of School Bus EMS crossing on a day	4.00%
Total Switching Trains	3.81%
Total Count of Flashing Light	3.78%
Maximum Time table Speed	3.50%
Day Thru Train Movements (6 AM to 6 PM)	3.24%
Total Trains	2.82%
Crossbuck Assemblies	2.81%
Night Thru Train Movements (6 PM to 6 AM)	2.26%
Crossing Surface	2.25%
In or Near City	2.03%
Does Track Run Down a Street	1.90%
Road Function	1.90%
Pavement Markings	1.84%
Highway Type	1.79%
Mast Mounted Flashing Lights	1.71%
Type of Land Use	1.64%

Factors or Variables	Importance
Roadway Gate Arms	1.48%
Main Tracks	1.36%
Number of Traffic Lanes Crossing Track	1.20%
Functional Classification Development	1.11%
Smallest Crossing Angle	1.10%
STOP Signs	1.06%
Bells	0.99%
Commercial Power Available Within 500ft.	0.97%
Is Crossing Illuminated	0.80%
Is Roadway Pathway Paved	0.59%
Advance Warning Signs	0.55%
Cantilevered or Bridged Flashing Light Structures Over Traffic Lane	0.42%
Crossing Type	0.36%
Other Flashing Lights or Warning Devices	0.32%
Signs or Signals	0.23%
Low Ground Clearance Signs	0.16%
Quiet Zone	0.07%
Crossing Position	0.07%
Highway Traffic Signals Controlling Crossing	0.00%

6. CONCLUSIONS

Highway-rail incidents at at-grade railroad crossings continue to be a major concern in the US because of the fatalities and injuries, as well as the massive financial burden, that results from such incidents. Louisiana continues to remain one of the top 10 states in the US with the highest number of reported highway-rail incidents, ranking 7th in 2017 with 87 incidents that resulted in 31 injuries and six fatalities. In its 2015 Statewide Transportation Plan, the state of Louisiana called for research into incentive programs that can be used to entice voluntary closure of at-grade railroad crossings. It was seen that reducing the number of potential vehicle-train collision points will increase safety at such crossings and reduce the number of highway-rail incidents. This study therefore sought to identify existing incentive programs being administered by US states, and also identify potential new programs that offer promise in reducing the number of crossings in Louisiana.

The information gathered from this study revealed that most incentive programs provided funding to cover a portion of safety improvement projects with regards to highway-rail crossings at significant costs to state agencies. Some programs require states to match 10% of the funds in order to obtain federal funding for projects, since most states prioritized qualifying for federal funding above obtaining other sources of funding. States such as Michigan, Nebraska, and Texas have had success with providing cash incentives to local governments when they decide to voluntarily close crossings. A percentage of states rely on one-time Legislative Appropriations to fund specific rail safety projects within a given year. To be able to support rail safety projects at the state and local level, states have also had success with regional funding mechanisms such as local sales tax and tax increment financing. Besides being funded either federally, by the state, or locally; safety projects can also be paid for by the railroad companies themselves. This can be seen in states such as Delaware where private-public partnerships have funded rail projects.

Information gathered from a nationwide online survey of DOT and railroad agency personnel showed that 16 out of the 38 states that responded had no incentive programs. The existing incentive programs for the remaining 22 states that responded were either expensive and unpopular, or not effective enough based on the information we have got from the online survey. The survey responses showed that track relocation incentive program was more effective, albeit expensive to implement. Cash incentives on the other hand, were very popular but not as effective in recent times. This observation was further supported by analysis of data from the RIMS database where it showed that states with track relocation incentive programs had a higher proportion of closed crossings than states that offered cash incentives. In addition, the study was able to establish a correlation between states that had some form of incentive program and states with a higher proportion of closed crossings. This can be seen in states such as Delaware, Maine, South Dakota, and Arkansas which have crossing closure rates of 15%, 29%, 33%, and 34% respectively. These states do not implement any incentive program for consolidation. However, states with incentive programs such as Nebraska, Iowa, Minnesota, and New Hampshire have crossing closure rates of 49%, 48%, 47. 5% and 47% respectively. Louisiana, with such high numbers of highway-rail incidents, currently offers no

incentive program for closure of its at-grade railroad crossings, even though specific railroad agencies may.

Based on the findings of this study, it is recommended that the state of Louisiana adopts some form of incentive program. However, due to the ineffectiveness or impracticality of existing incentive programs, the study identified three new potential programs, mostly, focused on improving the quality of life of Louisiana residents. These are crime rate reduction incentives, greenness improvement programs, and the development of a grade crossing consolidation model that considers safety, among a plethora of other factors, to be used to prioritize crossings to be closed. A consolidation model could include crime rate factors and greenness factors in the list of factors upon which a mathematical rating formula can be developed. The choice of which factors to include in any consolidation model is critical to the effectiveness of the model. The study was able to use Machine Learning algorithms to select the most important factors out of about 40 factors listed on the RIMS database. When a selection of 27 such factors were presented to Louisiana railroad representatives – through a second online survey only targeted at Louisiana residents – to rank, the results supported those identified by the machine Learning Algorithms. The survey results also supported closure/consolidation of highway-rail crossings as a means of reducing non-traffic related crimes such as robbery, vehicle burglary, and assault. Additional work is however required to develop such a consolidation model for statewide deployment. If successful, it will offer a formula-based and systematic approach to evaluate and prioritize crossings for closure or consolidation. The prioritized list of crossings may be used to convey the need and opportunity for closures to decision makers and stakeholders.

7. RECOMMENDATIONS

This study was able to establish that states with a form of incentive program for closure or consolidation of highway-rail crossings usually have higher proportions of closed crossings. It also established that consolidation models offer a weighted-index method of prioritizing which crossings can be consolidated or closed and, in addition, can be used to quickly investigate the feasibility of a possible closure or consolidation. The study was able to demonstrate how a plethora of factors – to be used in a consolidation model - can be reduced to few important factors through the use of Machine Learning algorithms. However, the study stopped short of developing a full-blown consolidation model.

The research team recommends additional research into the development of a consolidation model for the state of Louisiana that will not only include all the factors identified in this report, but additionally, the following:

- Crime risk: Closure of a crossing affects the accessibility of streets, thereby creating fewer escape routes for offenders. Where sidings are removed, the opposite effect may arise.
- Demographic information: Having the demographic information of residents may affect which incentive program may work in an area. Some characteristics of an area, such as age and education, may have a direct relationship with daily traffic and land use.
- Number/Severity of accidents: The number and severity of accidents which occurred at a crossing could be an indicator of how dangerous a crossing is.
- Greenness: consolidation of crossings improves the greenness of the neighborhood. In another words, after closures, the area of impervious surfaces in the vicinity is reduced.
- Proximity to evacuation routes: Highway-rail crossing closures may affect accessibility to evacuation routes.

Such a consolidation model will provide an objective and sound scientific methodology to support public and railroad agencies in making decisions related to consolidation or closures of at-grade railroad crossings. Where necessary and appropriate, cash incentives or some other existing identified incentives may be offered in addition to foster community cooperation.

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APPENDIX A: NATIONWIDE SURVEY QUESTIONS

Hello!

The purpose of this survey is to identify and evaluate incentive programs used to encourage closure of public and private railroad at-grade crossings in the United States. To participate in this study, you must be a state or railroad agency personnel with knowledge of railroad grade crossing issues. Your privacy will be protected in that no names of personnel will be revealed in the final report. This study has been approved by the LSU IRB. For questions concerning participant rights, please contact the IRB Chair, Dr. Dennis Landin, 578-8692, or irb@lsu.edu.

By continuing this survey, you are giving consent to participate in this study, for which we greatly appreciate.

Name and contact information of investigator: Dr. Julius Codjoe, jcodjo1@lsu.edu, (225) 767-9761

1. Please provide your contact information.

   - o Full Name:
   - o Email:
   - o Company:

2. State:

▼ Alabama . . . Wyoming

3. Some incentive programs for railroad closure/ consolidation are Cash Incentives, Nearby Roadway/ Crossing Improvements, and Track Relocation programs. Does your state/ agency offer or administer an incentive program(s) for closure of at-grade crossings?

   - o Yes
   - o No

4. Which type of Incentive Program(s) does your state/ agency offer or administer?

   - ▪ Cash Incentives
   - ▪ Road Improvement
   - ▪ Nearby Crossing Grade Separation
   - ▪ Nearby Crossing Improvement
   - ▪ Track Relocation
   - ▪ Other

5.1. Please provide any information on your "Cash Incentive" program.

5.2. How long has your Cash Incentive program been in effect?

- Less than 5 years
- 5 – 10 years
- 11- 15 years
- 16 – 20 years
- Over 20 years

5.3. How effective is your Cash Incentive program in achieving your goals of railroad closure/ consolidation?

Effectiveness

5.4. In your view, what are the reasons for not having a very effective Cash Incentive program?

6.1. Please provide any information on your "Road Improvement" program.

6.2. Long How long has your Road Improvement program been in effect?

- Less than 5 years
- 5 – 10 years
- 11- 15 years
- 16 – 20 years
- Over 20 years

6.3. How effective is your Road Improvement program in achieving your goals of railroad closure/ consolidation?

Effectiveness

6.4. In your view, what are the reasons for not having a very effective Road Improvement program?

7.1. Please provide any information on your "Nearby Crossing Grade Separation" program.

7.2. How long has your Nearby Crossing Grade Separation program been in effect?

- Less than 5 years
- 5 – 10 years
- 11- 15 years
- 16 – 20 years
- Over 20 years

7.3. How effective is your Nearby Crossing Grade Separation program in achieving your goals of railroad closure/ consolidation?

Effectiveness

7.4. In your view, what are the reasons for not having a very effective Nearby Crossing Grade Separation program?

8.1. Please provide any information on your "Nearby Crossing Improvement" program.

8.2. How long has your Nearby Crossing Improvement program been in effect?

- Less than 5 years
- 5 – 10 years
- 11- 15 years
- 16 – 20 years
- Over 20 years

8.3. How effective is your Nearby Crossing Improvement program in achieving your goals of railroad closure/ consolidation?

Effectiveness

8.4. In your view, what are the reasons for not having a very effective Nearby Crossing Improvement program?

9.1. Please provide any information on your "Track Relocation" program.

9.2. How long has your Track Relocation program been in effect?

- Less than 5 years
- 5 – 10 years
- 11- 15 years
- 16 – 20 years
- Over 20 years

9.3. How effective is your Track Relocation program in achieving your goals of railroad closure/ consolidation?

Effectiveness

9.4. In your view, what are the reasons for not having a very effective Track Relocation program?

10.1. Please provide any information on your "Other" program.

10.2. How long has your Other program been in effect?

- o Less than 5 years
- o 5 – 10 years
- o 11- 15 years
- o 16 – 20 years
- o Over 20 years

10.3. How effective is your Other program in achieving your goals of railroad closure/ consolidation?

Effectiveness

10.4. In your view, what are the reasons for not having a very effective Other program?

11.1. Do you have different incentive programs for closure of private versus public grade crossings?

- o Yes
- o No

11.2. Please list the different incentive programs you have for closure of private grade crossings.

12. Does your state see any of the following as a potential to reduce the number of at-grade railroad crossings?

Find other budget sources to increase existing cash incentives:

- Raise awareness of grade crossings safety issues
- Establish laws to assist closure of public and private crossings
- Design a holistic consolidation model considering other aspects beyond safety, e.g., social factors, environmental effects, and economic conditions
- Other

APPENDIX B: RESPONSES TO NATIONWIDE SURVEY

Table B-1. Organizations who participated in the nationwide survey.

Company:
Alaska Department of Transportation and Public Facilities
Alaska Railroad Corporation
Arkansas & Missouri Railroad
Arkansas Department of Transportation
Ashland Railway, Inc.
BNSF Railway
Cloquet Terminal Railroad
Colorado Public Utilities Commission
CSX Transportation
Delaware Department of Transportation
Delta Southern Railroad
Farmrail System, Inc.
Florida Central Railroad
Fort Worth & Western Railroad
Huntsville & Madison County Railroad Authority
Idaho Transportation Department
Illinois Central Railroad Company
Illinois Commerce Commission
Illinois Department of Transportation
Indiana Department of Transportation
Kankakee, Beaverville, and Southern Railroad
Kansas Department of Transportation
Louisiana Department of Transportation and Development
Maine Department of Transportation
Michigan Department of Transportation
Minnesota Department of Transportation
Mississippi Department of Transportation
Mississippi Export RR
Montana Department of Transportation
Nevada Department of Transportation
New Mexico Department of Transportation
New Jersey Department of Transportation
Norfolk Southern Corporation
North Carolina Department of Transportation
North Dakota Department of Transportation
Ohio-Rail Corp.
Ohio Rail Development Commission
Oklahoma Department of Transportation
Oregon Department of Transportation
Oregon Pacific Railroad
Pinsly Railroad Company
Port of Oreille Valley Railroad
San Luis Central Railroad
Santa Fe Southern Railway
South Carolina Department of Transportation
South Dakota Department of Transportation
Tennessee Department of Transportation
Utah Department of Transportation
Virginia Department of Transportation
Watco Companies LLC
Western New York & Pennsylvania Railroad, LLC
West Tennessee Railroad

Company:
West Virginia Department of Transportation
Wisconsin Department of Transportation
Wyoming Department of Transportation

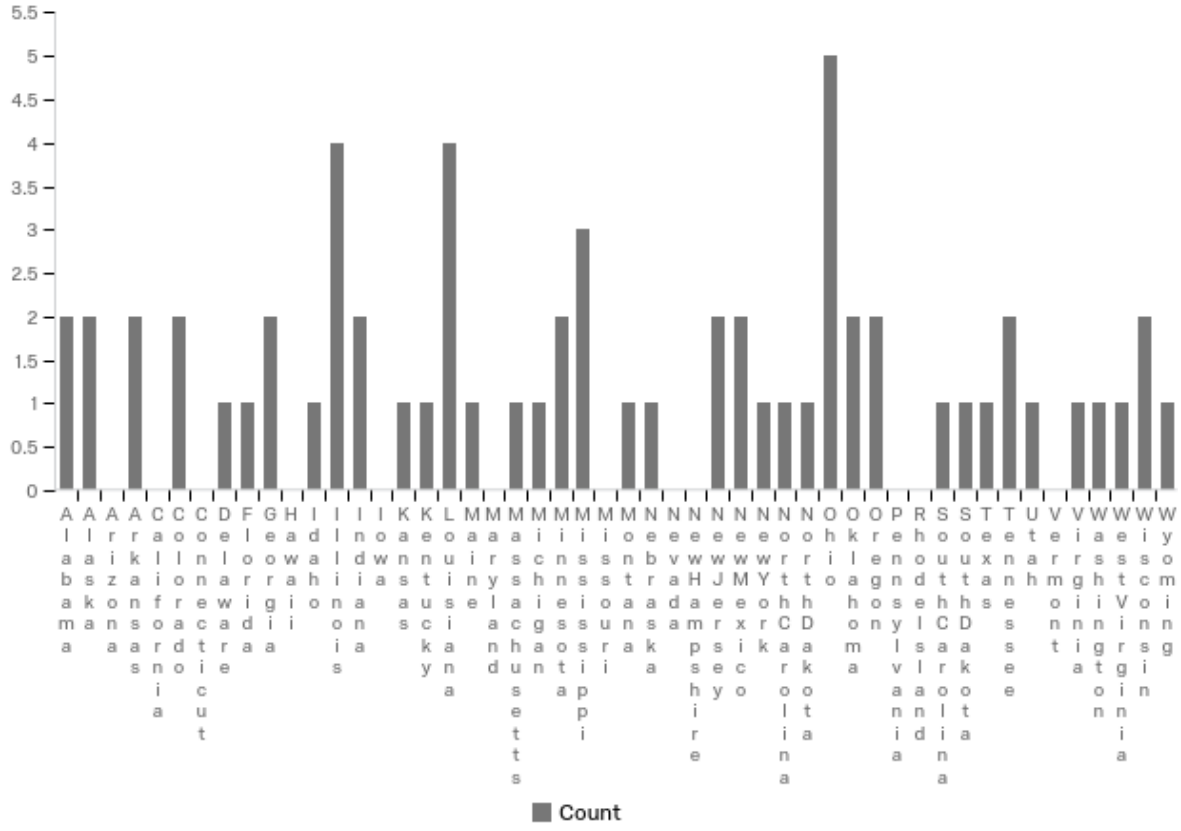

Figure B-1. Histogram of respondents of the nationwide survey by state.

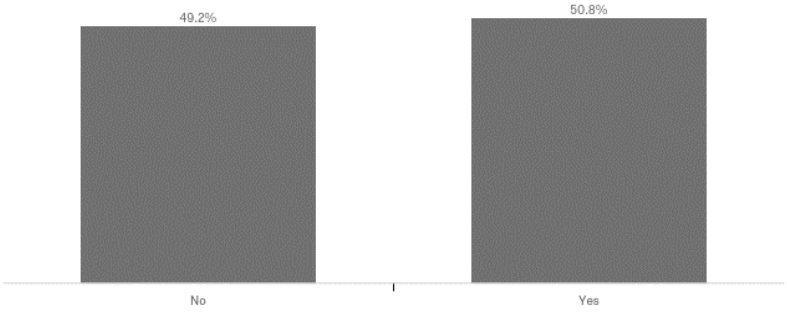

Figure B-2. Breakdown of whether respondents' agency/state offer incentive programs for closure of at-grade crossings.

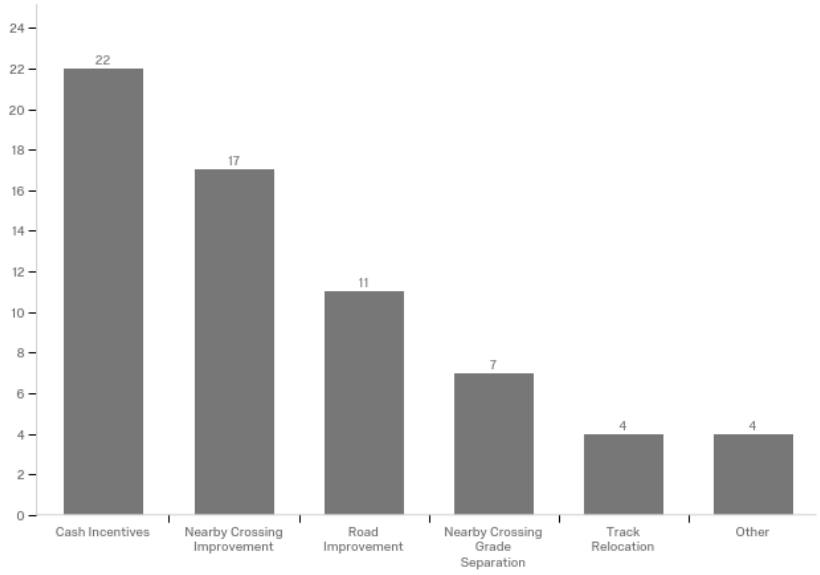

Figure B-3. Breakdown of type of incentive program offered by the respondent's state/agency.

Table B-2. Respondents' description of their agency's cash incentive program.

Organization	Response
Huntsville & Madison County Railroad Authority	The HMCR has not applied for this incentive, but it has been discussed on an at-grade crossing on our line.
Wisconsin Department of Transportation	State of Wisconsin offers only $7,500 per crossing if voluntarily vacated by local highway authority. This is usually matched $7,500 by the operating railroad. Total of $15,000 per public crossing.
Illinois Department of Transportation	The Illinois DOT provides cash incentives from the Federal Section 130 Funds. These funds are capped at, up to, $7,500 per crossing and are a match to any incentives that come from the railroad for the closure.
CSX Transportation	The Ohio Rail Development Commission (ORDC), the Public Utilities Commission of Ohio (PUCO) and railroads typically work together on projects to close at-grade crossings. The public funding offers are limited in terms of the scope and use, but cash offers from the railroad can be used by the local government for any purpose.
Illinois Commerce Commission	Hwy. Traffic Vol. (ADT) < 250 250 - 500 > 500 Amt. of Incentive Pymt. $50,000 $60,000 $70,000.
Tennessee Department of Transportation	Tennessee offers up to $7,500 cash incentive for public grade crossing closure to local governments as a match to railroad company incentive payment for closure, per 23 USC 130(i).
Norfolk Southern	The state does offer cash incentives but localities rarely take them as them for two reasons. First, the cash incentives tend to be relatively small ($7,500 on average). Second, the officials in charge of the closures are generally elected. There is not political will, even with cash incentives, to close them even over the objections of a few residents.
Ohio Rail Development Commission	Ohio offers a cash incentive of up to $7,500.00, matched by railroads, for a total of up to $15,000.00, that may be used for pre-approved highway safety improvements. Some railroads offer an additional cash incentive. A package is prepared based on community needs and railroad participation
Wisconsin Department of Transportation	We will use federal dollars to match up to $7500 of railroad funds. The $7500 must be used for traffic safety improvements in the community. Wisconsin does not have any state funds available for closure incentives.

Organization	Response
Minnesota Department of Transportation	In addition to paying for the work necessary to facilitate a closure, we will offer incentive payments. Mn Statutes 219. 074 Subd. 2 established a crossing vacation program in 1992. Although the reporting requirement expired, the statutes remains. However, MnDOT has never proceeded with a closure that was not supported by the local government.
NJ Dept. of Transportation	Cash incentive is in accordance with the FHWA $7,500. 00 matched by the Railroad.
Indiana Department of Transportation	The Crossing Closure program is one element of the Railroad Grade Crossing Fund (RRGCF). The RRGCF was established by Indiana Code as a way to improve safety at railroad/highway intersections. A local public agency can receive a cash incentive of a minimum of $10,000 to permanently close a crossing.
Michigan Department of Transportation	Based on public crossing characteristics, lump sum incentives for road agencies to permanently close a road at a crossing start at $50,000 and range up to $150,000 in state funding. If a road agency closes two or more crossings simultaneously, we add a 25% multiplier to each crossing award. Incentives are for public crossings only. Private crossings are not eligible.
Illinois Central Railroad Company DBA CN	In order to encourage communities to support closures, we offer a modest cash incentive, usually under $10K but can vary modestly, depending on characteristics of the project and how complicated the closure could be.
Norfolk Southern Corporation	Norfolk Southern uses a matrix to determine the cash incentive amount for a fully closed crossing. Additionally, Norfolk Southern works with State Department of Transportation agencies and the Section 130 program to participate in crossing consolidations, which includes crossing closures and improvements to adjacent crossings.
Norfolk Southern Corporation	NS uses a matrix that attempts to calculate and mitigate risk based on incident history, ADT, train volume, train speed, passenger service, number of tracks and current type of warning devices.
Illinois Central Railroad Company DBA CN	The Railroad will match the States contribution, at this time the state offers $7,500. 00. With the Railroad the total incentive is 15,000. 00. The municipality is required to draft a plan of what they will do with the incentive money for approval. Once approved the municipality will complete the work then invoice the state to receive the states portion. The Railroad does not require this, we will send the municipality the incentive money once an agreement to close the crossing is executed.
Norfolk Southern	We have a state funded crossing closure account. While there is no cap on the amount of money we can offer per crossing closure, we typically stick with the $7,500 that is noted in Section 130 code.
Michigan Department of Transportation	Previous MDOT Rail staffs have offered as much as $25,000 per closure as of about 8-10 years ago. I know the program has been around for at least 11-15 years, but it may have been around for longer, I'm not sure.
Nebraska NDOT	We provide $5,000 for closures and another $12,000 for actual costs associated with the closure for barricades, etc.

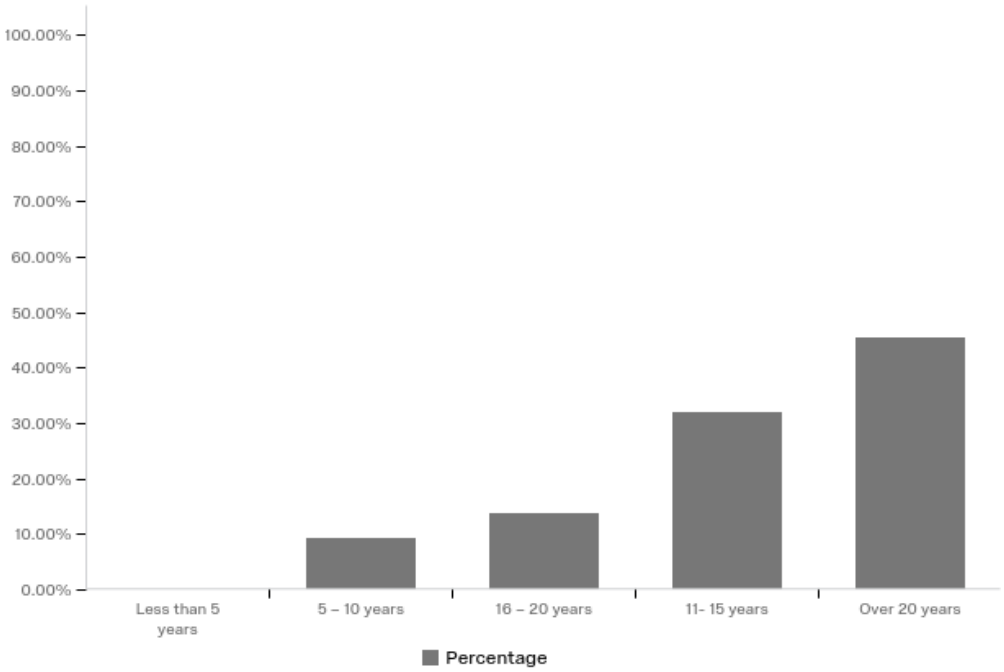

Figure B-4. Number of years each respondent's state/agency have had a cash incentive program.

Table B-3. Effectiveness of their state/agency's cash incentive program (as rated by the respondent).

Field	Minimum	Maximum	Mean	Std. Deviation	Variance	Count
Effectiveness	1.00	4.00	2.29	0.98	0.97	21

Table B-4. Respondents' reasons for not having an effective cash incentive program.

Organization	Response
Huntsville & Madison County Railroad Authority	The State should promote this program more. Our railroad is in favor of closing at-grade crossing that do not serve the public needs.
Minnesota Department of Transportation	$7,500 is not enough incentive for local governmental entities to effectively convince the public of the benefits of consolidation
Watco Companies LLC	Low cash incentive, not worth the troubles of the closure. Too much local political pressure against crossing closures.
Illinois Department of Transportation	Some municipalities simply do not want to close crossings. This could be due to political pressure from County/City/Town/Village Boards, changes to emergency response times, impacts to local businesses, or they simply do not see a need (no crash history) to close a crossing.
Alaska Department of Transportation and Public Facilities	Limited resources by the railroad and unrealistic demands by local governments.
Tennessee Department of Transportation	The maximum federal funds amount ($7,500) allowed under 23 USC 130(i) is not enough to be considered a significant incentive by most local governments facing public backlash for the closure.
Norfolk Southern Corporation	See previous answer. It would be helpful in most situations to remove the politics from a closure and have them looked at by an independent party. Close a few in this manner and the cash incentives would likely yield better results.

Organization	Response
Ohio Rail Development Commission	The value of the cash incentive is insufficient to provide a substantive benefit to the community. Assuming railroad participation and the full $15,000. 00 cash incentive, there is little that can be achieved that would offset the inconvenience of losing a crossing. Offering other safety improvements are more useful for obtaining closures, but only when those safety improvements help meet some other community goal such as a quiet zone. For the cash incentive to be meaningful it should be of greater value with few or no 'strings' attached.
Wisconsin Department of Transportation	$7500 isn't very much money and usually doesn't do anything to change the community's mind one way or the other it is just a bonus to whatever the railroad would be able to provide in cash.
Minnesota Department of Transportation	Local governments do not always react positively to a cash incentive. It can be viewed as a bribe. Locals may put a high value on access and would not agree to a closure for any (reasonable) incentive amount.
New Jersey Department of Transportation	I have asked this question to FHWA to increase the Cash amount and for this to be done, it will take approval in Washington DC.
Indiana Department of Transportation	Communities are simply hesitant to close at-grade crossings. People do now want to change their daily commute routine.
Indiana Department of Transportation	One element is the reluctance of communities to close or consolidate crossings. A second reason may be the low cash amount, which is under review to determine how much it should be raised.
Illinois Central Railroad Company	In our experience, even if we offer enhanced cash incentives or other considerations, such as supporting the widening of an adjacent crossing or creation of a connecting road so as not to disadvantage motorists, the issue can be that the community is so emotionally protective of redundant crossings that they will not support a closure almost no matter what we offer.
Norfolk Southern Corporation	The cash incentive offer is only a small piece of grade crossing safety and is more effective with crossing consolidation/corridor projects. Road authority participation is also necessary for an effective program.
Norfolk Southern Corporation	The incentive levels are typically not enough to offset the closure by offering levels that would pay for construction of or improving existing alternate routes. We are also by ourselves in many states as the only other incentive is a match using Section 130 funds at a minimal level, $7,500. Obtaining that match is often a cumbersome process for such a small amount. If FHWA would standardize the way states administer those funds, and increase the allowable levels, more crossings could be closed versus installing warning devices all over the place.
Mississippi Department of Transportation	People hate closing railroad crossings (or change in general). I've been a part of some very generous offers from railroad companies to local jurisdictions to close crossings and they don't have much of a chance from the start. People don't want the crossings closed, they want them to have lights/gates and smooth crossing surfaces and they want someone else to pay for it. Throw in a general disdain for railroad companies and the rate of success is very low.
Nevada Department of Transportation	Communities are not interested in cash incentives any more. They view it as a payoff. The amount of the cash incentives does not seem to be a motivator, some railroads have offered $250,000 or more for some closures and still they were denied.
Michigan Department of Transportation	Previous MDOT Rail staffs have offered as much as $25,000 per closure as of about 8-10 years ago. I know the program has been around for at least 11-15 years, but it may have been around for longer, I'm not sure.

Table B-5. Respondents' description of their agency's road improvement program.

Organization	Response
BNSF Railway	Railroads have incentive funds available to public roadway authorities (for Public Road crossings) and private landowner (Private Road crossings) to assist with funding of roadway improvements (performed by the roadway owner) associated with the closure of at-grade crossings and re-routing of vehicular traffic to alternate open crossings. The railroad's crossing closure funds are to be used at the discretion of the roadway owner.
BNSF Railway	Railroads do not have "ROAD" improvement programs. Railroads do have incentive funds available to public roadway authorities (for Public Road crossings) and private landowner (Private Road crossings) to assist with funding of roadway improvements (performed by the roadway owner) associated with the closure of at-grade crossings and re-routing of vehicular traffic to alternate open crossings. The railroad's crossing closure funds are to be used at the discretion of the roadway owner.
North Carolina Department of Transportation	Will offer road improvements, widening, new location road to mitigate for crossing closure.
Illinois Department of Transportation	Our Sec. 130 funds can be used for roadway improvements but this usually goes along with an upgrade to the existing warning devices from passive to active.
CSX Transportation	As part of a package deal, public agencies and railroads may offer to improve other roads to create connectivity for the traveling public over fewer grade crossings in an area.
Tennessee Department of Transportation	The maximum federal funds amount ($7,500) allowed under 23 USC 130(i) is not enough to be considered a significant incentive by most local governments facing public backlash for the closure.
Illinois Commerce Commission	The Illinois Commerce Commission (ICC) has the statutory responsibility to improve safety at public highway-rail crossings in the State of Illinois. Currently, there are 7,651 highway-rail grade crossings in Illinois, of which 765 are on state roads, and 6,886 are on local roads. There are 2,685 highway-rail grade-separated crossings (bridges) in the state. Another 3,649 grade crossings are on private property, which are not under the jurisdiction of the state, and there are also 140 private bridge structures. There are also 320 pedestrian grade crossings and 98 pedestrian grades separated crossings (bridges) in Illinois. Nationally, Illinois is second only to Texas in the total number of highway-rail crossings. The ICC orders safety improvements at public highway-rail crossings on the local road system, with the cost of such improvements paid by the state, the railroads, and local governments. On state roads, the Illinois Department of Transportation (IDOT) pays the majority of the costs through the State Road Fund. For local roads, the Grade Crossing Protection Fund (GCPF) was created to pay the majority of the costs of improvements. Illinois is one of the key transportation hubs in the nation. With approximately 7,400 miles of railroad track, its rail system is the country's second largest, including the nation's largest rail freight hub in Chicago. Illinois has the nation's third largest highway system, with 146,890 miles of highways, streets and roads and 26,724 bridges as of December 2015. Both the rail and highway systems are among the most heavily used in the nation in terms of volume of traffic, with much of the traffic concentrated in the Chicago metropolitan region. There, the urban mass transit system serves an average of over 623 million passengers a year over an extensive network of bus and rail routes. The Grade Crossing Protection Fund (GCPF), appropriated to the Illinois Department of Transportation but administered by the ICC, was created by state law to assist local jurisdictions (counties, townships and municipalities) in paying for safety improvements at highway-

Organization	Response
	railroad crossings on local roads and streets only. Assistance from the GCPF cannot be used for safety improvements at highway-rail crossings located on the state road or highway system. Those improvements are paid for by the Illinois Department of Transportation. Beginning with Fiscal Year 2010, each month $3. 25 million in state motor fuel tax receipts is transferred from the Motor Fuel Tax (MFT) fund to the Grade Crossing Protection Fund. This amount provides the GCPF with $39 million annually to be used for safety improvements at highway-rail crossings on local roads and streets. The GCPF is typically used to help pay for the following types of projects: Warning Device Upgrades: Installation of automatic flashing light signals and gates at public grade crossings currently not equipped with automatic warning devices; installation of automatic flashing light signals and gates at public grade crossings currently equipped only with automatic flashing light signals; signal circuitry improvements at public grade crossings currently equipped only with automatic warning devices; Grade Separations - New and Reconstructed: Construction, reconstruction, or repair of bridges carrying a local road or street over railroad tracks (overpass); construction, reconstruction, or repair of bridges carrying railroad tracks over a local road or street (subway); Grade Separations - Vertical Clearance Improvements: Lowering the existing highway pavement surface under a railroad bridge to improve vertical clearance for motor vehicles; Pedestrian Grade Separations: Construction of a bridge to carry pedestrian/bicycle traffic over or under railroad tracks; Interconnects: Upgrading the circuitry at grade crossings where warning signals are connected to the adjacent traffic signals so that the two systems operate in a synchronized manner; Highway Approaches: Improvements to the portion of the public roadway directly adjacent to the crossing surface; Connecting Roads: Construction of a roadway between a closed crossing and an adjacent open, improved crossing; Remote Monitoring Devices: Sensor devices in the circuitry of grade crossing warning devices which immediately alert the railroad to any failures in warning device operations; Crossing Closures: Provide an incentive payment to local agencies for the voluntarily closure of public highway-rail grade crossings; and Crossing Surface Renewals: Up to $2 million in assistance annually can be allocated for crossing surface improvements. Crossing Closures: 1) If an existing public highway-rail grade crossing meets the Commission's minimum requirements for installation of automatic flashing light signals and gates, a project for safety improvements at the crossing is included in the Commission's 5-Year Crossing Safety Improvement Program Plan (Plan), and the LA agrees to a closure (abandonment of the roadway within the RR right-of-way), the RSS will recommend that assistance from the GCPF be used to help pay for the construction of a new connecting roadway or improvement of an existing roadway. The RSS recommends that the amount of GCPF assistance for the roadway improvements not exceed 85% of the cost to install automatic warning devices at the crossing proposed for closure. The RSS will recommend the remainder of the cost for the connecting road, and all costs associated with removing the crossing surface, warning signs or devices, and erecting permanent barricades be paid by the RR. The LA will be responsible for all future maintenance costs associated with the barricades at the closed crossing. 1 Pertains to crossings closed as part of a larger safety improvement project only; see "Voluntary Crossing Closures" for information

Organization	Response
	regarding crossings closed by vacating roadways. These improvements may be accomplished through the use of the ICC Stipulated Agreement Procedure. 2) If a proposed crossing improvement/closure project is not in the Plan, a written request must be submitted to the RSS by the LA or the RR or a Petition must be filed with the Commission by one of the parties. Following receipt of a written request, the RSS will review the project to determine when the proposed improvements can be added to the Plan. If the Administrator recommends the project be added to the Plan immediately, the parties will be notified and asked to submit cost estimates for the proposed work as soon as possible. (Note: If the parties have been discussing a crossing improvement/closure project and are in agreement on the scope of work and the cost, submittal of a detailed cost estimate for the proposed work with the written request would help the RSS expedite the project.) If the RSS recommends the project be added to the Plan, but at a later date than what was proposed, the sponsoring party involved will be notified of this decision in writing. Following receipt of a Petition for proposed safety improvements, an Administrative Law Judge will set the matter for hearing, and all parties will be advised of the hearing date. 3) If an adjacent crossing requires the installation of automatic flashing light signals and gates, and/or highway approach improvements, the RSS will recommend assistance from the GCPF, not to exceed 85% of the cost to install automatic warning devices at the crossing proposed for closure, be authorized to help pay for the connecting road. The RSS will also recommend the GCPF be used to pay the local roadway authority's portion of the automatic warning device installation at the adjacent crossing. If adjustments to the existing highway approach grades are required, the RSS will recommend the local roadway authority be responsible for 100% of the cost to improve the highway approach grades at the adjacent crossing. The RSS will recommend the remainder of the cost for the connecting road, and all costs associated with removing the crossing surface, warning signs or devices, and erecting barricades be paid by the RR. The LA will be responsible for all future maintenance costs associated with the barricades at the closed crossing. 4) If a crossing equipped with automatic warning devices is proposed for closure, the RSS will recommend the cost division for the connecting road be determined based on the calculated capitol worth to the railroad of the closure. The RSS will recommend the future value of annual maintenance costs for the automatic warning devices and the crossing surface be considered the RR's share of the connecting road cost. The RSS will recommend the remainder of the cost be paid by the GCPF. The RSS will recommend all costs associated with removing the crossing surface, warning devices, and erecting barricades be paid by the railroad. The LA will be responsible for all costs associated with future maintenance of the barricades at the closed crossing. 5) For safety improvements involving multiple crossings, the RSS will recommend the LA receive credit toward the cost of installing automatic warning devices at one crossing in return for agreeing to close another crossing. The RSS will recommend to the Commission the GCPF be used pay up to 95% of the installation cost (standard 85% share plus the 10% share ordinarily paid by the LA) for automatic warning devices at the crossing that will remain open. The RSS will recommend the RR pay the remainder of the installation costs, along with all future operating and maintenance costs. 6) The RSS will recommend the cost to construct a connecting road, between the roadway where a crossing is to be closed and an adjacent roadway where the existing crossing will be equipped with automatic warning devices is located, be shared by the RR and the GCPF. Staff will recommend the RR share of the connecting road cost be an amount equal to

Organization	Response
	the Capital Worth1 of maintenance costs that the RR would have to pay out toward the existing surface and warning devices if the crossing proposed for closure were to remain open. 1 Capital Worth (cw) is also referred to as capitalized costs. The goal of determining capitol worth in this instance is to determine the amount a railroad would likely have to spend on maintenance of the crossing surface and warning devices. Example: GCPF Assistance = 0. 9 x (Cost of Signal Improvements at Crossing A + Cost of Signal Improvements at Crossing B) Cost of Signal Improvements at Crossing A = $150,000 Cost of Signal Improvements at Crossing B = $150,000 GCPF Assistance = 0. 9 ($150K + $150K) = $270,000 The RSS will recommend the GCPF pay all remaining costs for the connecting road construction after payment from the RR. The LA is responsible for all future maintenance costs for the new roadway. 7) For projects where other roadway improvements are required, in addition to construction of a connecting road, the RSS recommends the GCPF and the LA share the cost of the other improvements. The RSS recommends GCPF assistance for the construction of a connecting road and other roadway improvements be limited to 90% of what it would cost to install automatic warning devices at both grade crossings, if both were to remain open. The RSS could estimate annual maintenance costs but would rather have a railroad submit that information. Likewise, the RSS could assume an interest rate to be used to calculate the capitol worth value. But, the RSS would prefer to use an interest rate that is mutually agreeable to all parties. Example: Cost of Connecting Road = $100,000; RR Share = $60,000 (based on Cw of Crossing Maintenance Costs); GCPF share = $40,000 Capital Worth (Cw) = Annual Maintenance Costs (M) / Interest Rate (i) Where: M = $3000; i = 3% Cw = $3000 / 0. 05 = $60,000 Voluntary Crossing Closures - Any LA wishing to request Commission consideration of a GCPF incentive payment for voluntary closure of an existing public grade crossing must submit a Letter of Request to the Administrator. If the Administrator approves a crossing closure incentive payment request, the RSS will prepare a Stipulated Agreement for closure of the public highway-rail grade crossing(s) identified in the Letter of Request submitted by the local community. The Stipulated Agreement will be forwarded to all parties (LA, RR, and IDOT) for execution. The Stipulated Agreement will outline the scope of work and a division of costs for the required work. The local community will be required to pass an ordinance authorizing vacation of the roadway adjacent to the crossing that will be closed. [NOTE: The Roadway Vacation Ordinance must have an effective that is after the date of the Commission Order authorizing the GCPF incentive payment. Otherwise, the local community will not be eligible for the GCPF incentive payment.] A certified copy of the vacation ordinance must be submitted to the Rail Safety Section along with the local community's copy of the fully executed Stipulated Agreement. The local community will also be required to install temporary barricades at the crossing until a Commission Order, approving the closure incentive payment, is issued. Once a Commission Order is issued, the railroad will be required to install permanent barricades at the crossing, remove the crossing surface and all existing warning devices. The amount of the GCPF incentive payment a local community may receive is based on the annual average daily traffic volume (AADT) of the crossing proposed for closure. Grade crossings with an AADT less than 250 (<) are eligible for an incentive payment from the GCPF of $50,000. Grade crossings with an AADT equal to or greater than (>) 250, but less than or equal to (<) 500, are eligible for an incentive payment from the GCPF of $60,000. Grade crossings with an AADT greater than (>) 500 are eligible for an incentive payment from

Organization	Response
	the GCPF of $70,000. Hwy. Traffic Vol. (ADT) < 250 250 - 500 > 500 Amt. of Incentive Pymt. $50,000 $60,000 $70,000. If, in addition to the closure, automatic warning devices will be installed at an adjacent crossing to accommodate the rules for closure (92 Ill. Adm. Code 1536), the LA has the option of accepting the GCPF incentive payment and paying the local share of the upgrade or accepting a waiver of their portion of the upgrade in lieu of the GCPF incentive payment. The RR may also offer the LA additional closure incentive payments, without affecting the GCPF incentive payment. (NOTE: Multiple crossing closures are eligible for multiple incentive payments.) The RSS also recommends the LA negotiate directly with RRs for additional closure payments. If no crossing closure/connecting road improvements are considered as part of a corridor crossing improvement project (three or more crossings), a LA may submit a Letter of Request to the Administrator for a GCPF incentive payment for voluntary closure of a crossing.
Ohio Rail Development Commission	Road improvements are occasionally offered and are minor in nature. They are usually directly associated with the crossing closure, e. g. paving an alternate route. When not directly related to the closure, road improvements are usually related to safety at other grade crossings; e. g. surface reconstructions, profile improvements, etc. Other minor road improvements would be considered provided there is a safety need that is being addressed.
Minnesota Department of Transportation	This is not a separate program, but one of the solutions used to address grade crossing safety. This can include geometric improvements at /near the crossing, or in the case of a closure, improvement to roadways to facilitate reliable access at another crossing.
New Jersey Department of Transportation	We have made paving improvements to a roadway that would take the extra traffic.
Nevada Department of Transportation	We may provide funding for some connector roads, depending on length and complexity.

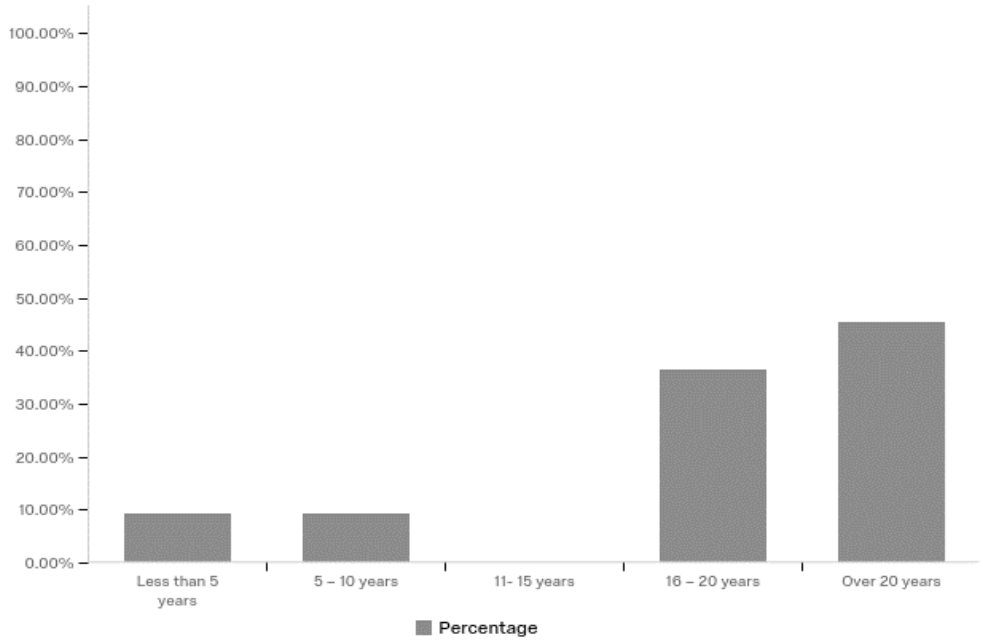

Figure B-5. Number of years each respondent's state/agency have had a road improvement program.

Table B-6. Effectiveness of their state/agency's road improvement program (as rated by the respondent).

Field	Minimum	Maximum	Mean	Std. Deviation	Variance	Count
Effectiveness	1.00	4.00	3.45	0.89	0.79	11

Table B-7. Respondents' reasons for not having an effective road improvement program.

Organization	Response
CSX Transportation	Unwillingness of local governments to participate.
Ohio Rail Development Commission	Road improvements are less effective than they could be because of the high cost of improvements relative to the amount of funding being offered. The amount of funding varies based on the crossing to be closed but would generally be in the $150,000.00 to $200,000.00 range. Right of way and environmental concerns limit the scope of what Ohio is willing to offer at this time.
Nevada Department of Transportation	Very costly concept.

Table B-8. Respondents' description of their agency nearby crossing grade separation program.

Organization	Response
Illinois Department of Transportation	Our Sec. 130 funds can be used for grade separation of a crossing.
Tennessee Department of Transportation	When bridges for grade separation are built for highway reconstruction (for increased capacity, safety, etc.), the existing at-grade crossing is usually closed.
Illinois Commerce Commission:	Grade Separations - The GCPF is used to assist Local Agencies (LAs) or RRs with the cost to reconstruct an existing bridge or construct a new bridge, both highway underpasses and highway overpasses. The GCPF is also used to help LAs with repairs to existing structures, such as improving vertical clearances at highway-rail underpasses by lowering the pavement. All projects involving the construction of new highway-rail or pedestrian-rail bridges crossings on the local road system shall be approved by Order of the Commission prior to the commencement of work on that project, regardless if whether the sponsoring agency is seeking assistance from the GCPF. The agency sponsoring the project shall file a petition requesting approval from the Commission to construct new highway-rail or pedestrian-rail bridge crossings on the local road system. For construction of a new highway-rail bridge crossing, or a new bridge that will replace an existing highway-rail grade crossing, the Illinois Commerce Commission's Railroad Safety Section (RSS) requires the project sponsor (LA or RR) to consider closure of other existing grade crossings in the vicinity of the proposed structure. The RSS believes that a new bridge crossing provides a safety improvement for a larger segment of a community than what an existing grade crossing serves. 1 The improvement, reconstruction, relocation or realignment of the highway approaches at any existing grade separation structure, including the installation of appropriate signing and drainage structures, and the minor alteration or reconstruction of any existing grade separation structure may be accomplished through the use of the ICC Stipulated Agreement Procedure. The establishment of a new public crossing by construction of a grade separation structure, the extension of tracks of a railroad company by grade separation, including construction of the highway approaches, the abolishment of any existing public grade separation structure, or the construction, major reconstruction, alteration or relocation of any grade separation structure may not be accomplished common) a RR financial contribution to the project is limited, depending on the type of other funds the local highway agency uses. If federal funds are

Organization	Response
	used, federal law (23 CFR 646B) limits RR participation to 5%. (Note: The 5% cap is for all railroad participation, regardless of the number of railroads involved in a project.) If the LA plans to use only state and/or local funds, the Commission has discretion to direct the RR pay an amount that is equivalent to the benefits derived from the safety improvement. If a RR agrees to pay the remainder of project costs, then the LA is not responsible for any project costs. Eligible work items include: Preliminary Engineering and Construction Engineering, Utility Relocation, Right-of-Way Acquisition, Bridge Construction, Any necessary Demolition, Roadway Construction (within "touchdown to touchdown" limits, including intersection construction), Railroad Force Account Work, Railroad Flagging & Railroad Protective Insurance, Safety Lighting, Connecting Road Construction (See Crossing Closures for cost division details on connecting roads.) Ineligible work items include: Traffic signal installation, Decorative roadway lighting, Decorative landscaping, Decorative sidewalk construction, Decorative walkway railings, Existing or proposed waterway structures located within the touchdown-to-touchdown limits are normally deleted from consideration when RSS staff calculates the eligible costs for that portion of a bridge project. Spans over proposed track(s) or service roads unless the "new" track(s) or service roads can be constructed within the RR's existing right-of-way limits. If the estimated GCPF portion of a bridge project is less than $4,000,000, and no grade crossing closures are involved, the RSS recommends the Commission's Stipulated Agreement process be used. If the GCPF portion of a bridge project exceeds $4,000,000, or grade crossing closures are included in the scope of work, the RSS recommends the Commission's Petition and Hearing process be used. However, the Administrator may determine if the Stipulated Agreement process is a possible option for any bridge project that meets the criteria noted above. A Petition is required for all new bridges (where no structure currently exists). A Petition is also required for all public highway-rail grade crossing closures, unless the LA agrees to vacate a roadway adjacent to a public grade crossing. The establishment of a new public crossing by construction of a grade separation structure, the extension of tracks of a railroad company by grade separation, including construction of the highway approaches, the abolishment of any existing public grade separation structure, or the construction, major reconstruction, alteration or relocation of any grade separation structure must be accomplished through the ICC Petition/Hearing process. This applies regardless if assistance from the GCPF is requested by the Petitioner. Pedestrian Bridges - As a result of a revision of state law in 2001, the ICC now has the authority to utilize the GCPF to assist LAs and RRs with the cost of constructing new pedestrian-rail bridges. Up to $2 million per year from the GCPF may be used for pedestrian-rail structures. Qualifying projects must meet the following criteria: The proposed location of the pedestrian bridge may not be within the right-of-way of an existing public highway/rail grade crossing; Public access must be available on both ends of the proposed structure Note, Policies for highway bridges, as outlined in Grade Separations above, also apply to pedestrian structures.
Norfolk Southern Corporation	This program was instituted legislatively in 2017. The state is still working on the mechanics of implementation.
Nevada Department of Transportation	Upgrading signal and/or circuitry.

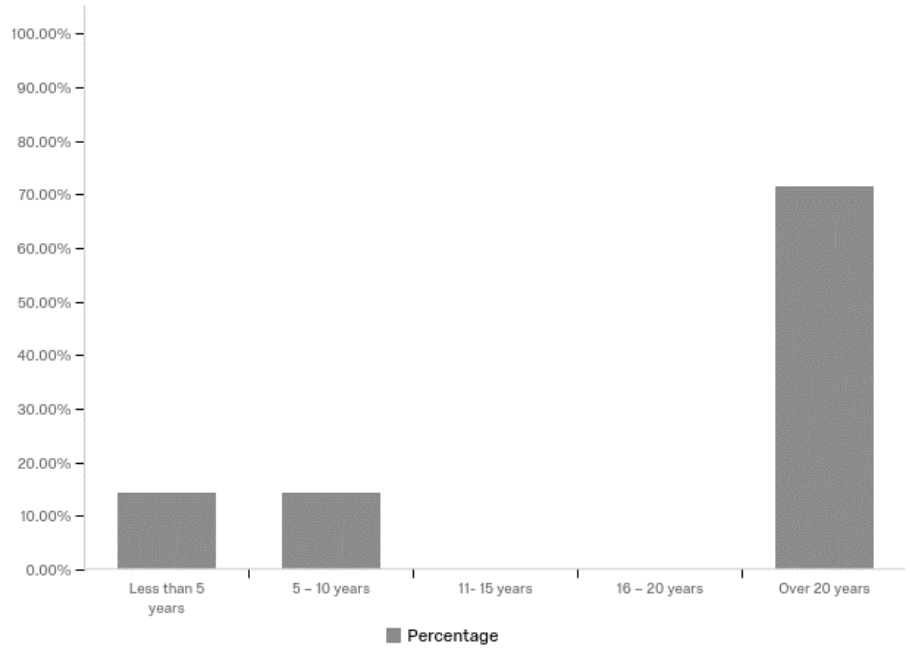

Figure B-6. Number of years each respondent's state/agency have had a nearby crossing grade separation program.

Table B-9. Effectiveness of their state/agency's nearby crossing grade separation program (as rated by the respondent).

Field	Minimum	Maximum	Mean	Std. Deviation	Variance	Count
Effectiveness	1.00	4.00	3.00	1.15	1.33	6

Table B-10. Respondents' reasons for not having an effective nearby crossing grade separation program.

Organization	Response
Illinois Department of Transportation	Grade separations can cost a lot of money. IDOT's Sec. 130 funds are limited to around $6 million for local roads and are to be used throughout the state. With this the funds given to a particular project might only be $500,000 or less. The agency would then have to find other funding sources to help with the project.
Tennessee Department of Transportation	Building bridges is expensive - they typically aren't built just to separate a highway from a railroad track. Other factors important to the public (i.e. economic development, part of a larger connectivity project, etc.) are needed have a crossing grade separation project.

Table B-11. Respondents' description of their agency's nearby crossing improvement program.

Organization	Response
BNSF Railway	The Railroad has incentive funds available to public roadway authorities (for Public Road crossings) and private landowner (Private Road crossings) to assist with funding of roadway improvements (performed by the roadway owner) associated with the closure of at-grade crossings and re-routing of vehicular traffic to alternate open crossings. The railroad's crossing closure funds are to be used at the discretion of the roadway owner.
BNSF Railway	The Railroads incentive funds available to public roadway authorities (for Public Road crossings) and private landowner (Private Road crossings) to assist with funding of roadway improvements (performed by the roadway owner) associated with the closure of at-grade crossings and re-routing of vehicular traffic to alternate open crossings. The railroad's crossing closure funds are to be used at the discretion of the roadway owner.
North Carolina Department of Transportation	Will improve adjacent crossing to mitigate for closure of at-grade crossing.
Illinois Department of Transportation	The Illinois DOT is willing to work with local agencies to close one crossing while improving others. When this is requested the local agency would receive cash incentives to close the crossing and while also receiving funding up to 90% to improve a nearby crossing.
CSX Transportation	The ORDC will offer to improve a nearby crossings (i. e., upgrade/improve warning devices) in exchange for crossing closures in communities.
Illinois Commerce Commission	See previous comments.
Tennessee Department of Transportation	We typically try to obtain federal funding authorization for improvements at a nearby crossing when a closure is being considered with the justification that upon closure the permanently detoured traffic will increase volumes at the nearby crossing causing a need for safety improvement. This additional work at a nearby crossing is an incentive to local government to make the closure.
Ohio Rail Development Commission	Crossing improvements include warning device upgrades and surface reconstructions. Generally, these are offered on a one for one basis - one closure for one improvement. However, based on cost and railroad participation other improvements may be included in the package offered for the closure.
Minnesota Department of Transportation	Again, this isn't a separate program. Improvements can include geometric, active warning or grade separation. However, the funds in our annual programs (~6. 5M federal, $1 M state) aren't able to support grade separations. Those are normally done through other program funds or bond requests to the legislature. The legislature did create a grade separation program last session, but no funds were allocated to it.
New Jersey Department of Transportation	Our other offer is to make crossing surface and railroad warning device improvements to the crossings north and south and allow the Town a surface improvement of their choosing.
Norfolk Southern Corporation	I would not really consider this a program but we often can widen a crossing surface as part of the deal to close other crossings.
Kansas Department of Transportation	It is with 402 funds.
Mississippi Department of Transportation	We will typically offer to put lights/gates at a nearby crossing in exchange for a closure. Usually, we try to get a closure per signal project.

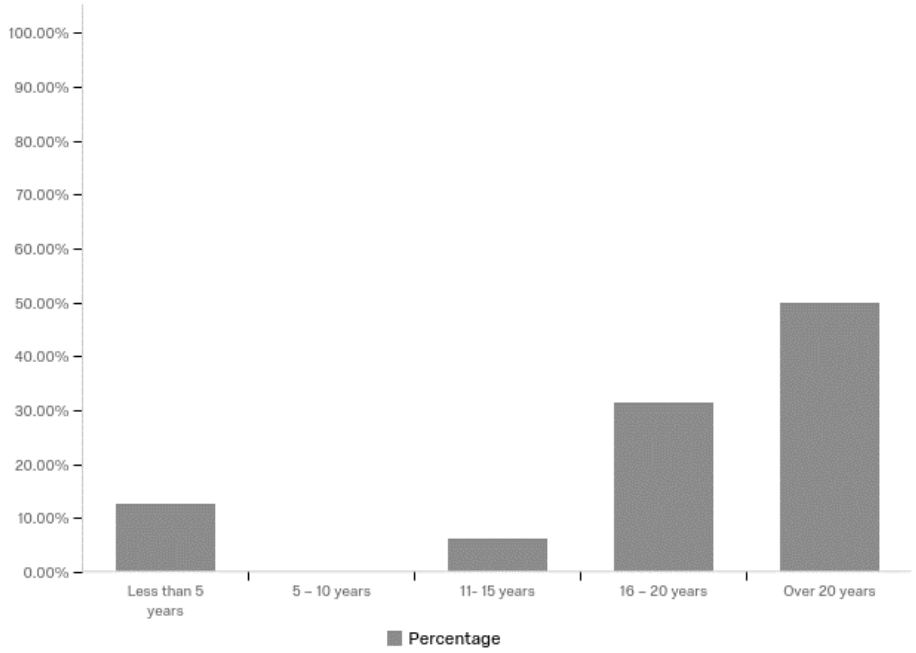

Figure B-7. Number of years each respondent's state/agency have had a nearby crossing improvement program.

Table B-12. Effectiveness of their state/agency's nearby crossing improvement program (as rated by the respondent).

Field	Minimum	Maximum	Mean	Std. Deviation	Variance	Count
Effectiveness	1.00	5.00	3.25	1.25	1.56	16

Table B-13. Respondents' reasons for not having an effective nearby crossing improvement program.

Organization	Response
CSX Transportation	Unwillingness of local governments to participate.
Tennessee Department of Transportation	Local governments will argue that both crossings (the proposed one for closure and the nearby crossing) should just both be improved because it is inconvenient or politically unviable to close a crossing.
Ohio Rail Development Commission	Communities often do not see nearby crossing improvements as an incentive because they believe the crossings should be improved regardless of a closure or the other crossings are adequate in their current condition. Nearby crossing improvements become a real incentive when the community is looking for other improvements such as a quiet zone.
Norfolk Southern Corporation	It is just a more uncommon desire for surface modification, communities are selfish and local politicians generally hold the final decision on what action they take. States could play a better role by taking the decision-making authority away from those who may not understand traffic engineering, railroad operations and future transportation planning.
Mississippi Department of Transportation	Same reasons as the cash incentive program.

Table B-14. Respondents' description of their agency's track relocation program.

Organization	Response
North Carolina Department of Transportation	Might do slight track relocation project as part of something like a grade separation project. Could be implemented to straighten a curve. Have also done a project to relocate switching operations away from urban congested area.
Ohio Rail Development Commission	Track relocations are rarely offered due to the cost involved. However, Ohio has always been open to track relocations as an option and recently negotiated the closure of a crossing on a U. S. highway and six other crossings.
Michigan Department of Transportation	We use a similar formula for crossing elimination attained by track relocation: awards based on public crossing characteristics, $50,000 minimum up to $150,000 in base awards, but with a 10% multiplier for eliminating more than one crossing at a time, and the award value is offered to the railroad as capped project participation. If the project costs less, we pay less. If the project costs more, the railroad pays the overage.
Kansas Department of Transportation	With 402 grant funds, state funds, railroad, and cities all working together for a better quality of life.

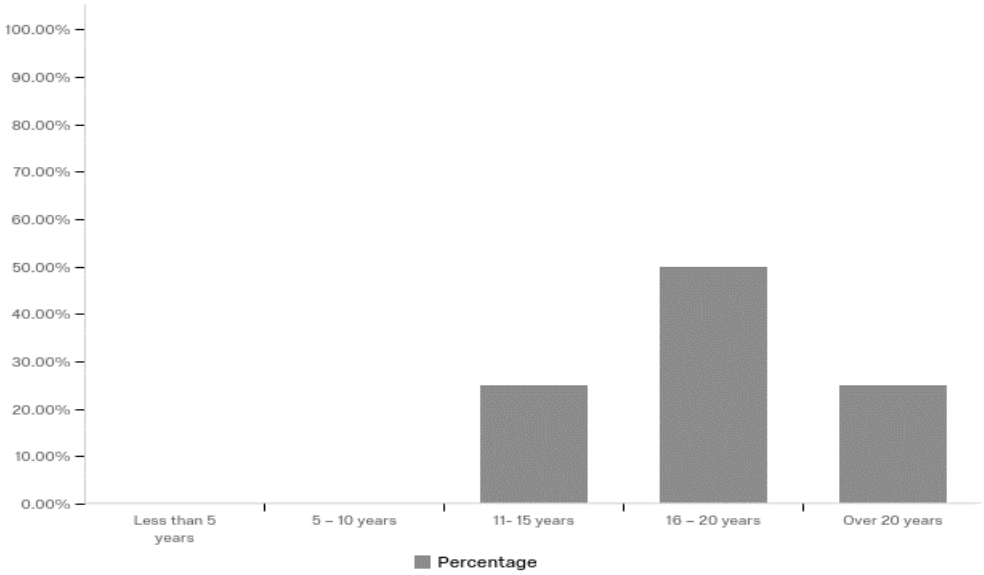

Figure B-8. Number of years each respondent's state/agency have had a track relocation program.

Table B-15. Effectiveness of their state/agency's track relocation program (as rated by the respondent).

Field	Minimum	Maximum	Mean	Std. Deviation	Variance	Count
Effectiveness	3.00	5.00	4.00	0.71	0.50	4

Table B-16. Respondents' reasons for not having an effective nearby track relocation program.

Organization	Response
Ohio Rail Development Commission	Track relocations are one of the tools in the toolbox. In the last 8 years there has only been one major track relocation project and this was extremely successful, resulting in a total of 7 closures. I have not rated it highly because it is so rare.

Table B-17. Respondents' description of their agency's "other" program.

Organization	Response
Utah Department of Transportation	See above.
CSX Transportation	Most recently, ORDC staff have been tying crossing closures to local interest in quiet zones by improving other crossings in the area to assist with FRA requirements to establish a quiet zone.
Illinois Central Railroad Company	This is not a specific program, but reflective of our willingness to address valid motorists;' concerns if local conditions indicate that there are legitimate objections against closure. It is not a universal program for every potential closure. It does provide some flexibility for a community who may support a closure, but only as long as certain local concerns are also addressed.

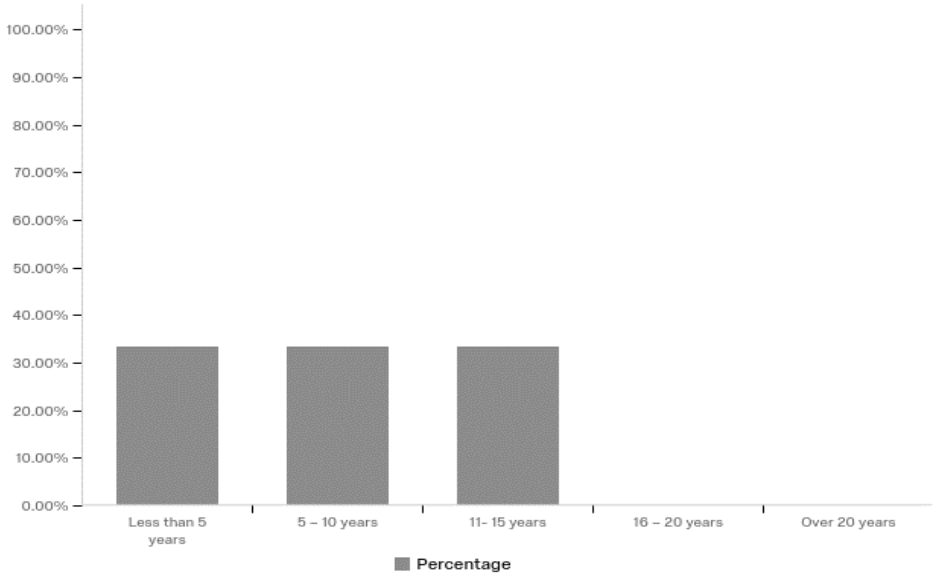

Figure B-9. Number of years each respondent's state/agency have had "other" program.

Table B-18. Effectiveness of their state/agency's "other" program (as rated by the respondent).

Field	Minimum	Maximum	Mean	Std. Deviation	Variance	Count
Effectiveness	2.00	3.00	2.33	0.47	0.22	3

Table B-19. Respondents' reasons for not having an effective "other" program.

Organization	Response
Virginia Department of Transportation	For many developed areas, finding crossings to be closed is quite difficult.
CSX Transportation	It is a relatively new approach and only been tried a few times in Ohio.
Illinois Central Railroad Company	Fierce citizen resistance that local political figures are not willing to go against.

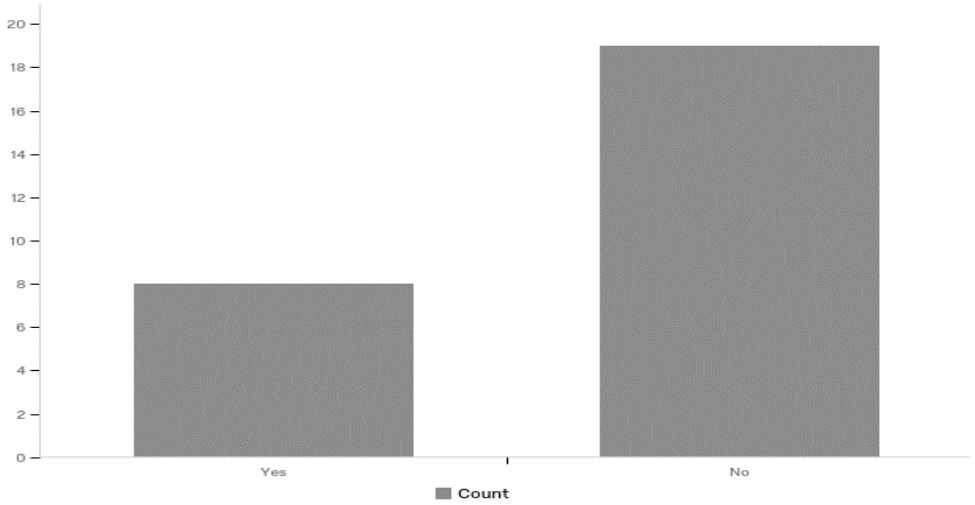

Figure B-10. Respondents' response to whether their state/agency has different incentive programs for closure of private versus public grade crossings.

Table B-20. Respondents' description of their agency's incentive program, specifically geared toward private grade crossings.

Organization	Response
North Carolina Department of Transportation	We are not allowed to work on private crossings in our state unless FRA gives approval. When we do work on a private crossing project the property owner will be compensated for right of way but will not be compensated monetarily by the State for crossing closure.
Montana Department of Transportation	Montana has no involvement with private at-grade crossings.
Illinois Commerce Commission:	The Illinois Commerce Commission's Rail Safety Improvement Program does not offer incentives for closure of private grade crossings.
Ohio Rail Development Commission	Ohio does not have any incentive programs for the closure of private grade crossings.
Wisconsin Department of Transportation	We don't have one.
New Jersey Department of Transportation	We do not participate in private crossing closures.
Norfolk Southern Corporation	I say yes in that ADT and the general absence of active warning devices decreases the matrix value on private crossings.
Mississippi Department of Transportation	We don't have any jurisdiction over private crossings and thus, don't have any role in opening/closing them.

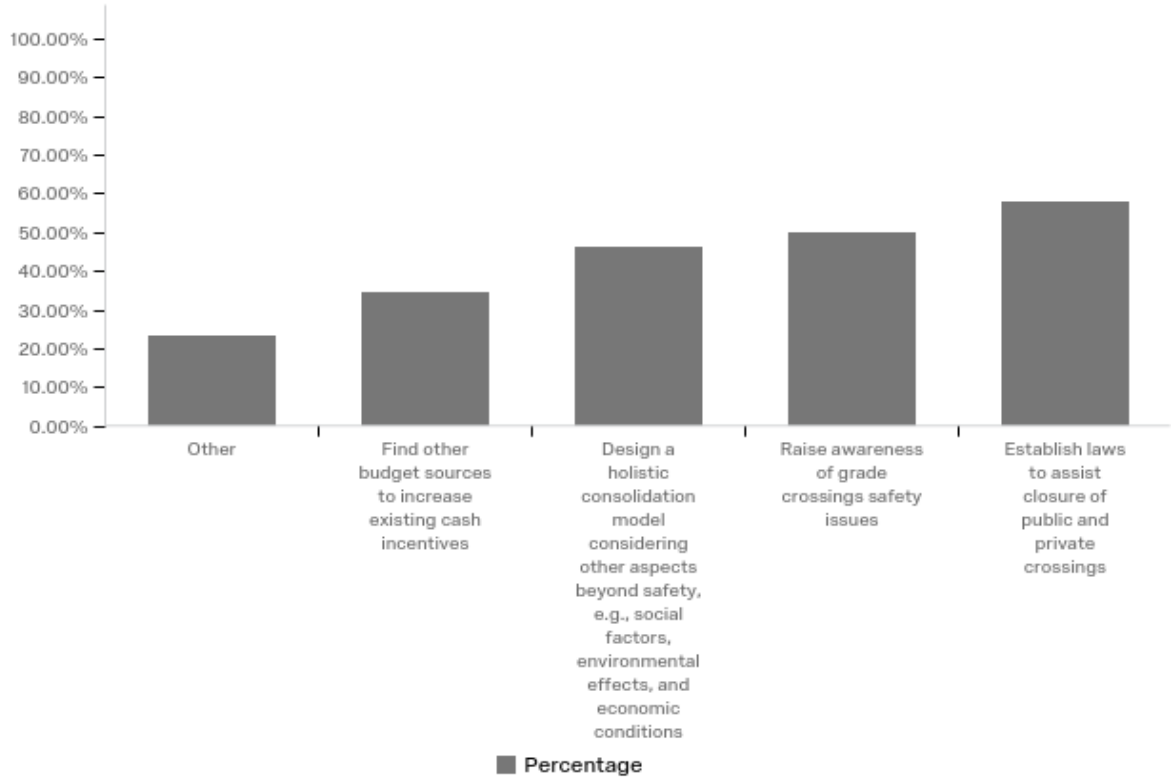

Figure B-11. Respondents' response to whether proposed strategies would reduce the number of at-grade railroad crossings.

APPENDIX C: LOUISIANA-SPECIFIC SURVEY QUESTIONS

Dear Railroad Safety/Industry Professional,

The Louisiana Department of Transportation and Development (DOTD) is investigating ways to reduce the number of potential vehicle-train collision points and one such option is to reduce the number of railroad grade crossings. As a railroad representative, we would like to know your views on closure or consolidation of railroad grade crossings within your jurisdiction.

Please spend few minutes to complete this 6-question survey. Any questions can be directed to the Principal Investigator: Dr. Codjoe (Julius. Codjoe@la.gov / 225-767- 9761).

Thank you for assisting.

1. Please write your contact details.

   Full Name:

   Email:

   Agency & Jurisdiction:

2. Do you consider vehicle-train collision or accidents at grade crossings a problem in your jurisdiction?

   O No

   O Yes

3. Do you support closure/consolidation of grade crossings as a means of reducing the non-traffic related crime rate in your jurisdiction? (Non-traffic related crime such as Robbery, Vehicle Burglary, Assault, and etc.)

   O No

   O Yes

   O Undecided

4. Do you support closure/consolidation of grade crossings as a means of reducing accidents at grade crossings?

   O No

   O Yes

5. Please indicate what you believe will be effective at reducing accidents at grade crossings in your jurisdiction:

6. Below is a list of factors that other state agencies/railroad experts consider when closing or consolidating grade crossings. Please select at least 3 factors you consider most important (rank 1 = most important) and at least 3 items you consider least important (rank 1 = least important). You may drag and drop in the appropriate box and move around to rank your choices.

- Intersecting roadway within 500 feet
- AADT
- Estimated Percent Trucks
- Number of school bus/ EMS passing on a day
- Flashing lights/ Active alarms
- Signs/ Passive alarms
- Typical train speed
- Typical vehicle speed
- Crossing surface
- Day through train movement
- Night trough train movement
- Crossbuck Assemblies
- Roadway gate arms
- Crossing illumination
- Type of Landuse
- Road function/ number of lanes
- Smallest angle of road and rail
- Bells / quiet zone
- Crossing type (private/public)
- Development (urban/rural)
- Roadway pavement condition (paved/not paved)
- Crossing purpose (pathway/highway)
- Disability and Bike Access
- Low ground clearance signs
- Location specific characteristic (flood/snow)
- Sight Distance
- Crime Pattern
- Other

APPENDIX D: RESPONSES TO LOUISIANA-SPECIFIC SURVEY

Table D-1. Organizations who participated in the Louisiana-specific survey.

Company:
BNSF Railway
CN Police Service
CN Railroad
Federal Highway Administration
Federal Railroad Administration
Kansas City Southern Railway
Louisiana Department of Transportation and Development
Moffatt & Nichol
Union Pacific Railroad

Table D-2. Respondents' reaction to various conditions regarding closures of public and private grade crossings

Condition	Field	Choice Count	Percentage
Whether respondents felt that vehicle-train collisions/accidents at grade crossings are a problem in their jurisdiction.	No	1	7.14%
	Yes	13	92.86%
Whether respondents support closure/consolidation of grade crossings as a means to reduce non-traffic related crime in their jurisdiction.	No	2	15.38%
	Yes	8	61.54%
Whether respondents support closure/consolidation of grade crossings as a means of reducing accidents at grade crossings.	No	0	0%
	Yes	13	100%

Table D-3. Top three important factors to consider when closing or consolidating grade crossings (as chosen by the respondents).

	Most Important Factors	
#	Factor	Count
1	AADT	6
2	Intersecting roadway within 500 feet	4
3	Development (urban/rural)	4
4	Sight Distance	4
5	Number of school bus/ EMS passing on a day	3
6	Road function/ number of lanes	3
7	Smallest angle of road and rail	3
8	Low ground clearance signs	3
9	Other	3
10	Flashing lights/ Active alarms	2
11	Signs/ Passive alarms	2
12	Typical train speed	2
13	Typical vehicle speed	2
14	Day through train movement	2
15	Crossing illumination	2
16	Estimated Percent Trucks	1
17	Night trough train movement	1
18	Crossbuck Assemblies	1
19	Roadway gate arms	1
20	Type of landuse	1
21	Crossing type (private/public)	1
22	Roadway pavement condition (paved/not paved)	1
23	Crossing purpose (pathway/highway)	1

	Most Important Factors	
#	Factor	Count
24	Disability and Bike Access	1
25	Crime Pattern	1
26	Crossing surface	0
27	Bells / quiet zone	0
28	Location specific characteristic (flood/snow)	0

Table D-4. Top three least important factors to consider when closing or consolidating grade crossings (as chosen by the respondents).

	Least Important Factors	
#	Factor	Count
1	Crossing surface	5
2	Crossing illumination	5
3	Bells / quiet zone	5
4	Roadway pavement condition (paved/not paved)	5
5	Type of landuse	3
6	Crime Pattern	3
7	Intersecting roadway within 500 feet	2
8	Typical vehicle speed	2
9	Location specific characteristic (flood/snow)	2
10	Estimated Percent Trucks	1
11	Flashing lights/ Active alarms	1
12	Signs/ Passive alarms	1
13	Typical train speed	1
14	Day through train movement	1
15	Night trough train movement	1
16	Crossbuck Assemblies	1
17	Roadway gate arms	1
18	Road function/ number of lanes	1
19	Crossing type (private/public)	1
20	Crossing purpose (pathway/highway)	1
21	Disability and Bike Access	1
22	Low ground clearance signs	1
23	Sight Distance	1
24	AADT	0
25	Number of school bus/ EMS passing on a day	0
26	Smallest angle of road and rail	0
27	Development (urban/rural)	0
28	Other	0