# HIGHWAY-RAIL GRADE CROSSING SAFETY: AN EXAMINATION OF VIEW OBSTRUCTION AND CROSSING ANGLE USING AERIAL PHOTOGRAPHY

BY

JOSEPH A. SEPULVEDA III
Department of Geography
Northern Illinois University, 2012

## Introduction

As we progress into the 21st century, the efficiency of rail transportation is growing. The U.S. Department of Transportation is projecting substantial increases in rail transport over the next three decades (Operation Lifesaver, 2012a). This rail growth along with increasing amounts of urbanization is resulting in more rail and highway traffic. Consequently, intersection development is rising and resulting in greater opportunity for collisions between train and vehicle. Because of these collisions, safety levels at highway-rail intersections continue to be the foremost concern among railway research. The rail industry must work to meet the safety challenges that accompany the current and upcoming population and rail growth. The primary focus of enhancing safety is generally through modifying crossing design. There is need for continual highway-rail crossing research as long as collisions are occurring at frequent rate, especially those that lead to fatalities.

With more than 250,000 public and private railway crossing in the United States there are many opportunities for rail collisions to occur (Federal Railroad Administration, 2012). According to the Operation Lifesaver (2012b), there were 1,956 highway-rail crossinf collisions in 2011 alone. That averages to over 5 collisions per day in the United States. Of those 1,956 annual collisions, 94 were in Illinois, 19 of which led to fatalities (Operation Lifesaver, 2012b). Fatalities that occur at highway-rail intersections are often preventable. Highway safety and railroad officials have responded by closing crossings, upgrading warning devices, and sponsoring safety initiatives such as Operation Lifesaver to warn drivers of the hazards of highway-rail intersections. These efforts have proven successful as the number of deaths and injuries from train/vehicle collisions has fallen by over 84% since 1975 (Operation Lifesaver, 2012b). Although the amount of vehicle/train collisions is decreasing, the 2,004 annual collisions is still an alarming total. It is apparent that there is still support needed in re-examining the safety of highway-rail intersections and to further explore what intersection characteristics that may lead to further highway-rail collisions. . (Please note that in this document the term grade crossings are synonymous with the terms “highway-rail crossings” and “highway-rail intersections.”)

## Background

Lack of visibility is a frequent factor when trying to assess the safety of a highway-rail intersection (Federal Railroad Administration, 2010). The angle of the intersection crossing can many times affect the amount of visibility between a vehicle and on-coming train. Currently there are no laws in place within Illinois that prevent intersection construction from being built at a hazardous angle (Compilation Laws FRA, 2002). It is vital to examine whether certain intersection angle are leading to a higher frequency of collisions. By better understanding the impacts of poor intersection visibility angles we judge what degree of angle is most hazardous and in turn can be eliminated.

There are few federal and state laws in place that mandate any sort of restriction on the visibility within intersections. Vegetation growth restrictions are some of the few laws that currently stand related to view obstruction. According to the compilation of federal and state laws published by the Federal Railroad Administration (2010), there are no nationwide laws against vegetation obstructing the view of highway-rail intersections to motor vehicle drivers, just laws against obstructing the view of the train conductor. However, some states have taken it upon themselves to implement such laws involving vegetation restrictions. For example, Alabama and Arizona don’t have any laws relating to vegetation as a view obstruction (Compilation Laws FRA, 2002). States including Illinois and Arkansas have employed their own regulations. The Illinois law requires that all crossings within the state must remove all brush, trees, vegetation overgrowth within five hundred feet in either direction from each crossing looking down the tracks (Compilation Laws FRA, 2002).

With adjustments to existing intersection laws and further assessment of intersection angles we can enhance railway safety. Whether changes arise from more effective urban development or through enhancing visibility within the intersection, the necessity for change is evident.

Past methods for studying highway-rail intersection safety have embraced numerous techniques. A 2004 study surveyed 752 drivers about the safety and effectiveness of railway crossing gates (Benekohal & Murat, 2004). The study concluded that crossing gates, flashing lights, clanging bells, and train horns were rated the most effective indicators in informing a driver of a highway-rail intersection (Benekohal & Murat, 2004). When examining the results, the passive intersection studied lacked half of the most effective warning indicators. 22% of surveyors said that there needs to be more warning devices/protection in passive and active intersections (Benekohal & Murat, 2004).

Previous research has introduced the concept of a “dynamic dilemma zone” (DDZ) road segment (Moon & Coleman III, 2003). Dilemma refers to the vehicles perception or reaction time, where the vehicle could not clear the intersection or stop before entering it (Moon & Coleman III, 2003). The DDZ model is a road segment that falls into the approach of a passive intersection (Moon & Coleman III, 2003). The road segment varies in length based on the vehicles speed and the number of vehicles within the road segment (Moon & Coleman III, 2003). When analyzing the DDZ model results showed that the speed of over 50% of all vehicles approaching the passive intersection was far too great for the vehicle to stop before entering the highway-rail intersection (Moon & Coleman III, 2003). This research studied a variable (speed) that my research does not.

My research will examine the relationship between view obstruction and its effect on intersection safety. This study examined people’s safety margin in relation to enhancing lateral sight distances at passive intersections (Ward & Wilde, 1996). To perform this study, two railroad crossings were observed, one with view obstructing trees along the railway and one with no view obstructions (Ward & Wilde, 1996). No safety gates were present at each of the sites. Results showed that drivers displayed longer search durations and slower speed approaches toward the highway-rail intersections where the trees where obstructing their view (Ward & Wilde, 1996). When there was no view obstructions drivers had faster approaches and shorter search durations (Ward & Wilde, 1996). Drivers exhibited an increase in perceived safety when view obstructions were low. The problem with these results is that there is very little statistical evidence other than observing the vehicles waiting longer. The size of the trees or how far away the trees were from the driver would have been useful to assess how big of a role the vegetation really does have. My work will build upon these findings by locating the exact point of which the drivers view is obstructed. This can then result in knowing what exactly to eliminate.

Another study was performed to assess the effectiveness of an active intersection in rural Indiana (Meeker & Barr, 1988). 57 drivers were observed crossing this intersection. Results showed that when vehicles were at the intersection alone, two thirds of the drivers drove around the safety gates when the train approaching was visible (Meeker & Barr, 1988). However, all but four drivers slowed down significantly or stopped prior to crossing the tracks illegally (Meeker & Barr, 1988). It was concluded that the driver's decision to cross was based on their perception of visual evidence (Meeker & Barr, 1988). This research further supports the need for addition safety analysis. In this instance it seems as though the lack of urbanization surrounding the intersection may have led to an increase in safety avoidance.

These studies have shown that it is vital to research railroad safety though more of an analytical approach. Although the above research did make significant observations, in some cases the simplicity took away from the validity. The aim of this research is to better understand the complexities of highway-rail intersection collisions and find out why and where they are occurring. This research will investigate whether different types of intersections and/or view obstruction play a role in intersection safety. These investigations will occur in the northern Illinois region.

## Research Design

### *Objective 1:*

The initial objective is to determine if the number of highway-rail intersection collisions between vehicle and train is influenced by the angle that the roadway crosses the rail tracks. The angle is defined as by vectors corresponding to the center of the road and the center of the tracks. In order to achieve a consistent degree measure, angles will start at the stop bar of the road segment and end 100 meters down the railway.

### *Objection 2:*

The second objective is to determine whether the number of highway-rail intersection collisions is influenced by view obstruction between the oncoming train and the driver of the motor vehicle. A view obstruction refers to any object that hinders the sight between the driver of the motor vehicle and the path of the train. These include, but are not limited to building infrastructure, elevation of tracks, sounds walls, and surrounding vegetation. Often time's drivers approach a highway-rail intersection not being able to see directly down the tracks. The sight obstruction of an approaching train may impact the driver's decision to cross the tracks illegally. The oncoming train has out of sight out of mind affect. Increased visibility of the train will have an effect the driver's decision making. If drivers can see a train approaching they may be less apt to take the risk of crossing the tracks illegally.

## Study Site

The fieldwork for this project will be conducted in zone 4 of the FRA's 8 divisional zones (Figure 1). Zone 4 consists of Michigan, Indiana, north-central Illinois, Wisconsin, and Minnesota. For the purposes of this research I will be focusing on Illinois. To ensure a manageable

*Figure 1. Displayed is the FRA's zonal map. This research will focus on zone 4.*

study area and sample size, three counties in Chicago’s metropolitan area will be the primary site of this research. These counties include Cook, DuPage, and Will (Figure 2). These three counties are serviced by 10,075 different sections of rail line (Figure 3) (Federal Railroad Administration 2010). Those rail lines comprise of 843 different highway-rail intersections (Federal Railroad Administration 2010). The selection process of highway-rail intersections studied will be covered within the methodology section.

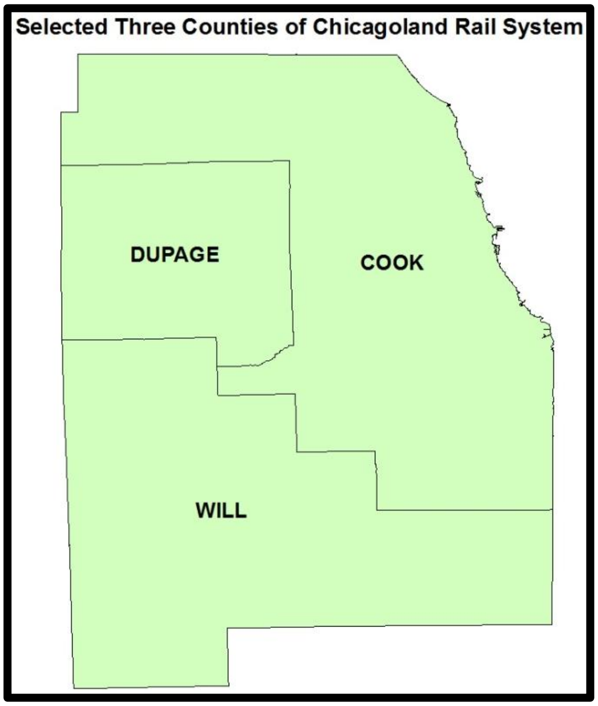

*Figure 2. Above are the three counties within the study area*

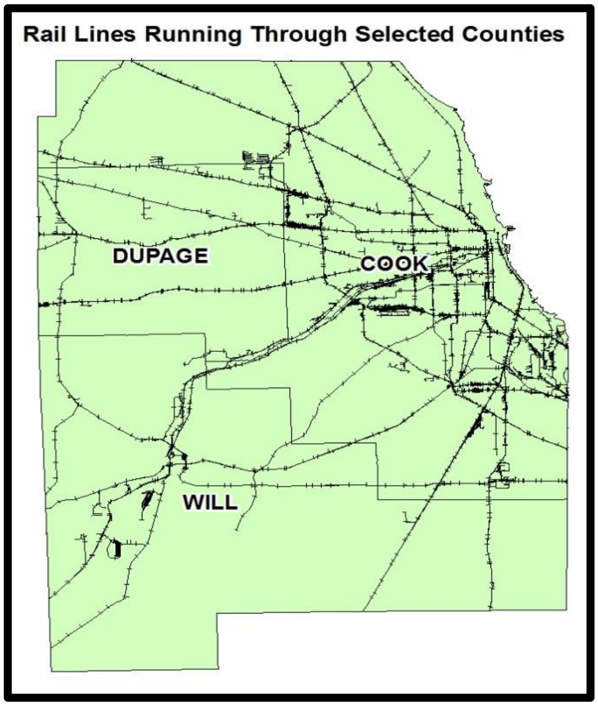

*Figure 3. Above are the rail lines that run through Cook, DuPage, and Will*

## Methods

The initial step is to gather the rail, highway-rail intersection, and accident data needed to perform the research. Using the FRA’s database, Illinois collision statistics were collected for all highway-rail crossings. Suicides, trespassers and all non-vehicle related crossing collisions were excluded from the dataset. From the Illinois dataset, the results are additionally refined. The collision data was further filtered to only include the three counties three counties within Chicago’s metropolitan region, Cook, DuPage, and Will. Since the FRA did not start recording highway-rail intersection collisions until 1975, no collisions occurring before 1975 and after 2010 will be used. To account for

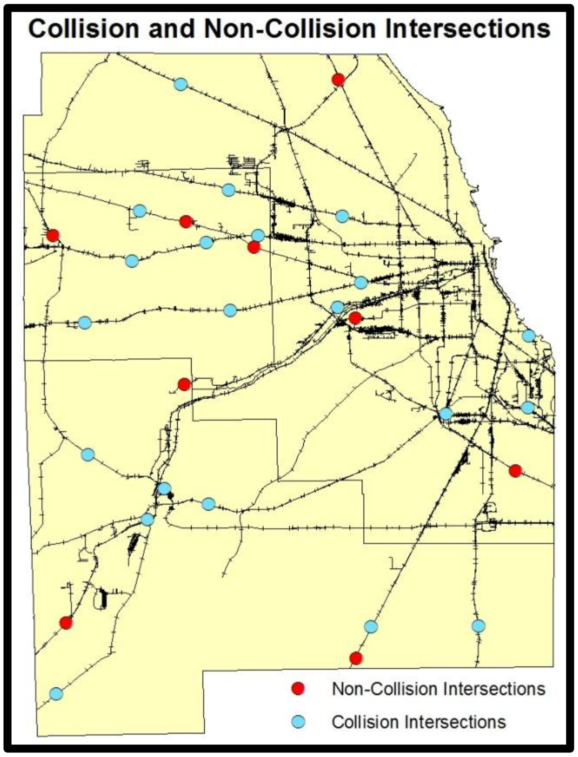

*Figure 4.Above displays the thirty intersection selections.*

infrastructure development around highway-rail intersections, a collision dataset ranging from the years 1990-2010 is used. Once the counties collision data is collected, seven collision sites will randomly be selected from each of the three counties. Additionally, three intersections will be chosen for each county that have not had a collision occurrence bringing the collision total to thirty (Figure 4). Null (non-collision) crossing locations are chosen for purposes of comparing site characteristics. This comparison between collision sites and non-collision sites will allow the identification of unsafe highway-rail crossing characteristics.

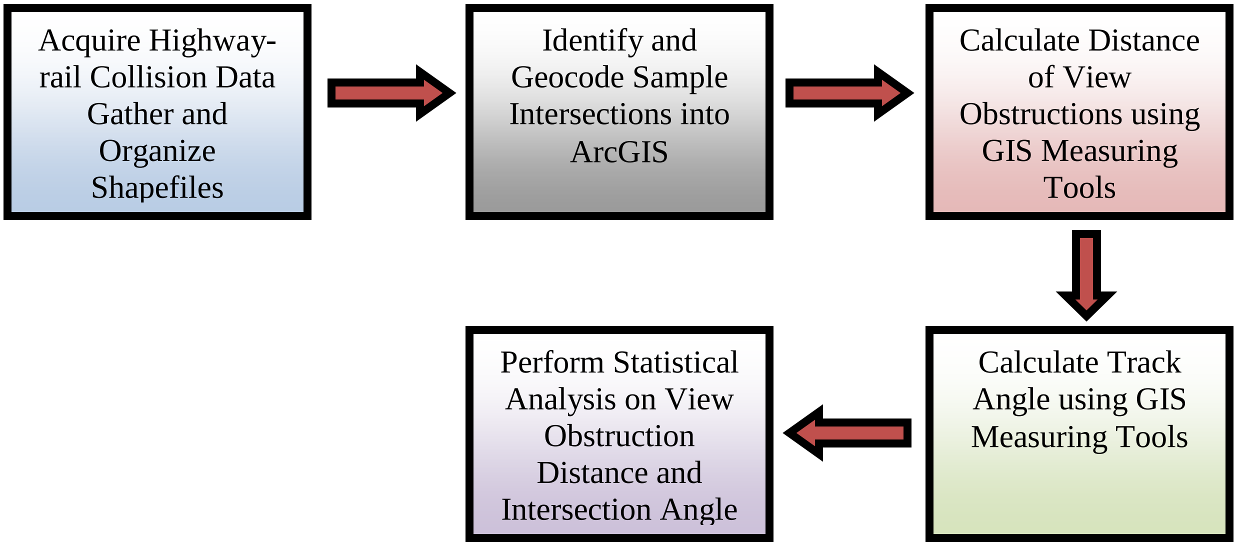

*Figure 5 .Above displays a flowchart of the implemented methodology.*

The primary spatial data elements necessary to calculate visibility measures include road geography, rail geography, and aerial imagery.  Road network data were extracted from TIGER 2000 data files from the U.S. Census Bureau. Rail network data was obtained from the Illinois Department of Transportation. Lastly, aerial imagery was provided from online data servers within the ArcGIS software (Bing Maps, USDA NAIP 2010). All GIS mapping and distance calculations were performed in ESRI's ArcGIS. Distance measurements were taken for 4 views (2 from either side of the crossing). Angle measurements were captured using GeoMedia Professional. Only 1 angle measurement was needed for each intersection. Between the 4 different crossing views and 1 angle measurement per crossing there was a total of a potential 5 variables that could influence highway-rail intersection collisions. All statistical analysis was performed in S-PLUS. Within S-PLUS, a generalized linear model was run. A Poisson regression test was used to determine the relationship between collision frequency, angle of the intersection, and distance of view obstruction.

## Results

Statistical analysis revealed that 3 of the 4 potential variables had a significant influence on highway-rail collision frequency (See Table 1). *View 2* was the only variable not to prove significant within the model. Of the 21 collision sites examined, 9 of them had view obstructions caused by infrastructure, 7 by vegetation, and 2 intersections contained both types of view obstructions. The average intersection angle of non-collision intersection was 69.8, while the average angle of collision intersections was 60.3. The average number of collisions per sampled intersection was 6.5. The root mean square error (RMSE) of the model variables was 1.2. This value reflects the precision of the model by measuring the differences between the predicted values. A RMSE of 1.2 validates that this model has an accurate representation of the data.

*Table 1: Below displays the statistical output of the collected highway-rail intersection data. Since no intersection contained 4 view obstructions, View 4 of omitted from the dataset. View 2 does not have a significant t-value and therefore, based on the model, does not influence collision frequency. View 1, 3, and intersection angle display values outside of the acceptance region and can be concluded as significant to influencing highway-rail collision frequency.*

| **Collision Frequency= f(View 1, View 2, View 3, Intersection Angle)** | | | |
|---|---|---|---|
| **Variable** | **Intercept** | **Std. Error** | **t-Value** |
| Intercept | 5.338112213 | 0.531089083 | 10.0512558 |
| View 1 | -0.003266414 | 0.000826431 | -3.952434 |
| View 2 | 0.000271808 | 0.001189358 | 0.2285337 |
| View 3 | -0.005116504 | 0.001784449 | -2.8672743 |
| Intersection Angle | -0.037713369 | 0.004092292 | -9.2157088 |

| RMSE: 1.21 |
|---|

## Conclusion

Determining what factors lead to highway-rail intersection collisions is vital to enhancing public safety. If view obstructions caused by infrastructure, vegetation, and intersection angle are increasing the likelihood of a collision, then new laws and restrictions need to be implemented. Through this research, the exact location of a view obstruction that occurs between the driver of the vehicle and the approaching train can be determined. Once the exact location is concluded, we now know what piece of infrastructure or vegetation needs to be re-examined. Mapping the characteristics of collision prone intersections can provide a more accurate assessment of where hazardous obstructions are located. Ultimately my hope is that Infrastructure and Vegetation will be closely monitored along rail tracks. This research will help make intersection environments a safer place. Effective research and statistics proving the cause of collisions and fatalities can further provide the FRA support when implementing additional laws concerning intersection safety on a nationwide level. There is not a proper assessment of why motor vehicles are colliding with trains. My hope is that research will continually be pursued concerning railroad safety. With further research we can continue progressing forward in identifying hazardous highway-rail intersection characteristics.

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