East End District: Transportation Study

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Abstract

The East End Management District (EED) partnered with the Hobby School of Public Affairs at the University of Houston to conduct an analysis of the EED's roadways and road user safety. The study aims to assess the factors contributing to severe traffic accidents and fatalities and what measures can be introduced to prevent them. The analysis employs a model that evaluates accident severity and contributing variables, such as time of day, road conditions and available safety features. The study also explores the socioeconomic vulnerabilities specific to the district's population.

The analysis results determined that the district's dangerous intersections were more prevalent in areas where the population presents with particular vulnerabilities to roadway accidents, such as those without vehicles, who bike or walk to work and who have lower socioeconomic status. In addition to the effects of traffic incidents on the population, roadway characteristics were also identified that increase the probability of a traffic accident. Intersections with four or more points of entry were found to be a significant risk factor. Higher speed limits are also driving up the rates of traffic accidents in the EED.

As a result of the analysis, the study presents several measures that could change the trajectory of traffic accidents in the EED. The model supports that the presence of traffic features such as traffic signals and railroad flags reduces the number of accidents. Conclusions drawn from the academic literature on traffic accident reduction also point to the installation of roundabouts and speed bumps can be particularly impactful in reducing the severity of accidents due to the lowering of speed. The models and analysis presented can be of great benefit to the residents of the EED. The district is a socially vulnerable community in need of infrastructure investment to improve its quality of life and safety as it continues to grow.

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1 Introduction

The traffic death rate in the United States continues to be the highest among the world's high-income countries. There were over 36,000 fatalities on U.S. roadways between 2016 and 2019. (Yellman et al., 2022). People, young and old, have lost their lives carrying out their daily routines on the country's roadways. The traffic safety community asserts these traffic fatalities are 100% preventable when the appropriate safety measures and behaviors are adopted by both road users and traffic systems such as seat belt usage, use of proper child safety seats, wearing of safety equipment like helmets and the broad implementation of the Safe Systems approach. (Centers for Disease Control and Prevention, 2023) All sectors of society have a role to play in reducing traffic deaths and serious injuries which is the very idea behind the foundation of the Safe System approach to traffic safety. This premise relates to the shared responsibility posed within the principles of the approach. Its principles are grounded in human-centered design thinking centered on a total of six principles overall: 1)deaths and serious injuries are unacceptable, 2)humans make mistakes, 3)humans are vulnerable, 4)responsibility is shared, 5) safety is proactive, and 6) redundancy is crucial. (Otto et al., 2022) By adopting measures that follow these principles, accidents can be eliminated because systems will accommodate common user errors and anticipate crash likelihood instead of reacting to past crashes. The safe systems approach implementations can reduce the severity of accidents by accommodating human vulnerability to factors such as high speed as well as utilizing roadway design to compensate for system failures, anticipating and reducing mistakes.

A safe system involves all stakeholders, from road users to government, nonprofits and the private sector. (Otto et al., 2022) Implementing traffic systems guided by these principles reinforces a proactive and human-centered transportation philosophy and system. Recognizing the fallibility of transportation end-users, rather than assuming perfection, can transform the design and implementation of safe road systems. This systems-level approach applies across the elements of roadways and their use. The five elements to follow are complementary to the previously mentioned principles, working together in order to achieve the approach's goals; encouraging safe road users through responsible driving behaviors and creating safe conditions for all road users, including pedestrians, cyclists, drivers, and all other transportation modes. It is crucial to have safe vehicles designed to lessen the frequency and severity of accidents and ensure collision reduction technology is widely available across vehicle models and implement safe speed limits. Further, safe roads can be achieved through infrastructure that addresses human error and implementing systems that alert all road users of hazards. Finally, post-crash care is a critical element that allows for quick response times to traffic incidents for emergency responders to deliver acute care and decrease the likelihood of fatality. This also includes crash site analysis to assess vulnerabilities and provide potential solutions. (Doctor Ngo, 2022) The system's emphasis on all elements working together underscores the importance of a systems-level response that involves all stakeholders.

The Safe System approach emerged in Sweden in the 1990s under the Vision Zero project.[1] The nation set an ambitious goal to end all traffic-related deaths and serious injuries. Over the decades, Sweden has brought this systems-level approach to fruition with camera technology speed monitoring, replacing multi-entrance intersections with roundabouts, an automotive in-

[1]See https://visionzeronetwork.org/.

dustry producing safer vehicles and vulnerable road users (VRUs) are prioritized in new urban developments. (Trafikverket, 2019) In the years following Vision Zero's adoption in Sweden, the country cut its already comparatively low traffic death rate in half. Despite the significant gains, the trajectory of the program's success has diminished. This has called for a renewed push for Safe System programs. Sweden transportation analysts conducted a 2018 study to assess the country's progress toward its 2020 goals of zero traffic fatalities. The results revealed there were 324 traffic related deaths, 35% higher than their target goal, which would have required no more than 240 deaths in the year 2018 to be in lin with their 2020 target. The reasons for the diminished gains pointed toward lack of adherence to safe driving speeds and safe cycling behavior along with impaired drivers. (Trafikverket, 2019) These results could indicate the measures adopted are not going far enough. Safety features along with measures to modify human behavior and choices are showing to be of great importance.

The same is true for countries worldwide that followed Sweden's adoption of Vision Zero. The gains in reductions in traffic accidents and serious injuries are on the decline. The number of traffic fatalities and serious injuries have increased in recent years, particularly during the pandemic. (Otto et al 2022) The renewed push by stakeholders has led to more cities taking on the Vision Zero challenge. Houston became one of 40 U.S cities to sign onto Vision Zero in 2019, which spurred a data and citizen-driven study of the city's roadways in pursuit of safe, accessible streets (City of Houston, 2020). Houston's participation in Vision Zero, with the aim of achieving Vision Zero's goals by 2030, is redirecting the city's trajectory from a car-dominant society to one that provides equitable and safe access to mobility for community members. Houston's Vision Zero plan focuses on motorists and VRUs. The National Safety Council defines VRUs as those utilizing roadways without protection from a collision, thus exposing them to significant injury or mortality if involved in a traffic accident. Such users include pedestrians, cyclists, operators of mobility devices such as wheelchairs and motorized scooters, and motorcyclists. (National Safety Council. 2018) The term VRU is further specified in Houston's pledge to focus on children and senior citizens in order to emphasize the safety of these particularly at-risk VRUs (City of Houston, 2020). Their age and mobility contribute to their vulnerability on roadways.

Figure 1: Total SVI Percentile Ranking and Fatal Accidents at Intersections in Harris County

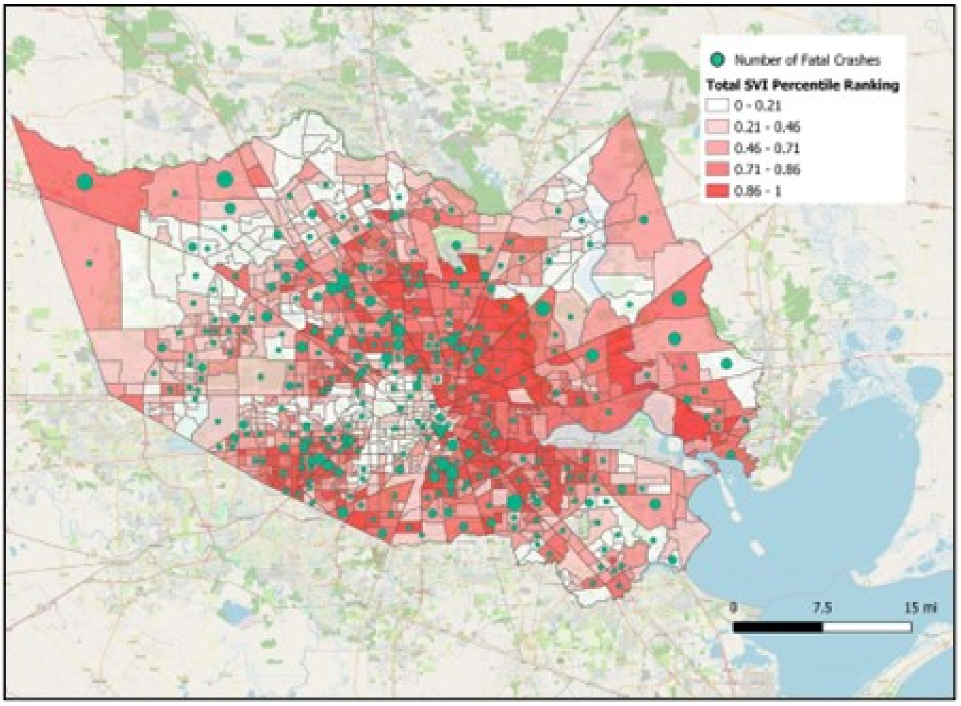
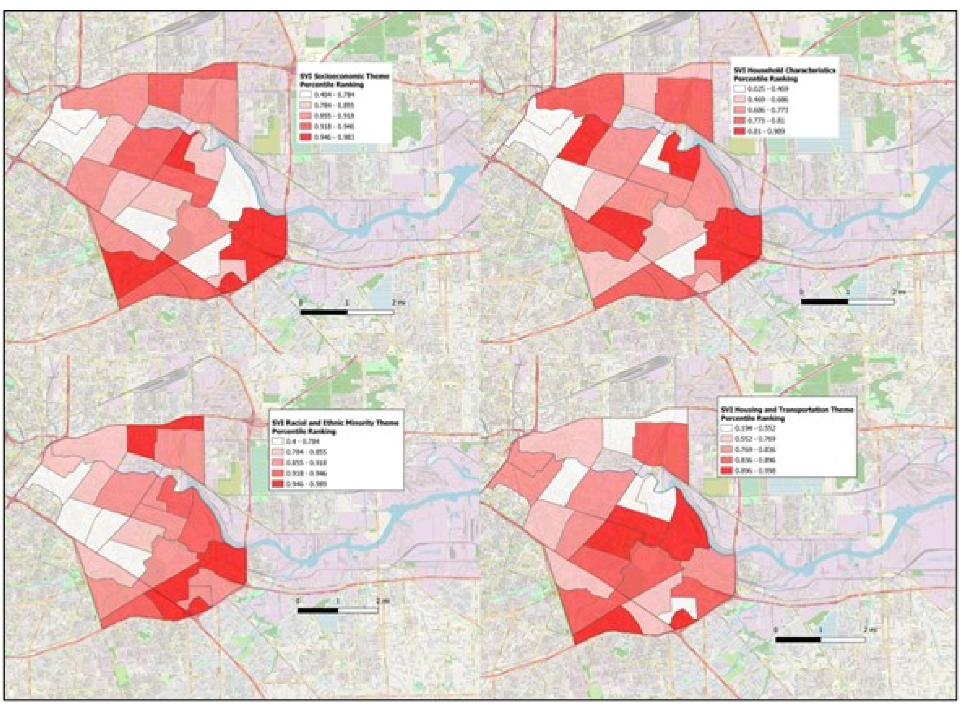


Figure 2: East End District Vulnerability by Individual Theme



To tackle the myriad of traffic issues and those most vulnerable, Houston constructed the comprehensive "Houston Vision Zero Action Plan" in 2020 through crash data analysis from the years 2014-2018, along with the Center for Disease Control's (CDC) Social Vulnerability Index database (SVI). Analysis of this data led to the creation of a priority action list informed by both the data and community input. There were over 50 action items, but the City prioritized 13 items, including communication strategy, implementing safe systems and speeds, and programming, described as various construction projects to improve safety conditions. The study also led to the identification of the High Injury Network (HIN), which is a representation of 6% of Houston's streets where 60% of fatal traffic accidents or serious injuries have occurred; the city further prioritized half-mile road segments with a significant number deaths, serious injuries, and pedestrian-involved crashes. (Grove, 2022)

While the high number of serious and fatal incidences is alarming, the disproportionate impact on those identified by the CDC as Socially Vulnerable is even more so. Fifty-two percent of roads included in the High Injury Network are in socially vulnerable neighborhoods. The Social Vulnerability Index measures individuals living in poverty, crowded housing, and lacking access to transportation as being at the highest risk of infrastructure failings such as a weather-related crisis or mobility issues. (CDC/ATSDR, 2022) This is particularly alarming given the region's propensity toward climate-related disasters and transportation challenges. As can be seen in Figure 1, there are larger numbers of fatal crashes are concentrated in Harris County's census tracts in the higher percentile of the CDC's SVI ranking.

One of the socially vulnerable communities identified with the HIN is the East End District (EED). The EED comprises 16 square miles, where the municipal entity provides services and neighborhood improvements through a collection of assessments from businesses operating within its boundary (East End District, 2023). It is a small district charged with setting a foundation for the impending growth that will come to the area as development and interest continues. While it is a relatively small district, the SVI rankings in Figure 2 illustrate the confluence of social factors such as socioeconomic, household characteristics, and concentration of ethnic/racial minorities along with housing and transportation barriers, that differ across the District which can either increase or decrease its vulnerability. An example is particular tracks with low socioeconomic vulnerabilities but higher on the rankings for transportation themes due to larger numbers of pedestrians and cyclists.

2 Literature Review

Previous literature suggests that the physical characteristics of road design influence the rate of car accidents (Lum, Reagan 1994). Even though drivers are typically blamed for accidents, road design and lack of maintenance greatly contribute to accident rates. Studies comparing U.S. and UK accident rates find that 27% of all accidents can be attributed to the interaction between the road environment and drivers (Lum, Reagan, 1994; Elvik, Langeland, Sageberg, 2019; Malik et al 2017). Similarly, Tay (2015), using crash data from Canada from 2008-2012, finds that intersections disproportionately lead to accident rate increases. Furthermore, previous literature utilizing crash data from Belgium from 2010-2015 finds that intersections, skewed intersections, more entries into intersections or roads, and multiple through lanes lead to higher rates of accidents (Khattak et al, 2021). Multiple intersections or entries into roads are more susceptible to human error as they require drivers to make keen decision making with these intersections and entry points which increases the chance for human error.(Samyajit Basu et al,2022;Kai, Wang et al, 2015)

Road environment and types also play a part in contributing to accident rates. A study on urban roads in Denmark identifies that roads linked to parking lots, shopping centers, and high building-density areas contribute to increased accident rates. Additionally, roads with multiple access points and high amounts of minor side roads have higher accident risks (Grebie,2003). The reasoning for this is that having cars enter roads from multiple entry points can cause more collisions as drivers may have an error on observing the road they are entering.(Kai Wang et al,2015) Furthermore, high-density areas may have more cars driving around in compact areas which may lead to more accidents. Research that gives further credence to road design and maintenance of roads impacting accident rates is that research from the UK shows that investment in a safe infrastructure program would yield about a third decrease in roadside deaths (Road safety foundation, 2008). For Houston specifically, previous research shows that serious car accidents are more likely to happen at intersections, roads with multiple entry points, and in large commercial areas and typically happen during rush hour and happens on highways/merging onto highways. (Li, Sui,Zhu 2007; Sun et al,2022) Research shows that roads with a lack of maintenance in Houston and that are saddled with poor conditions, such as potholes, unexpected bumps, and overall road degradation also contribute to an increase in car accidents in Houston. (Atatah, 2015)

Road characteristics are not the only external physical influence on accident rates, as previous studies have showcased that overall traffic congestion influences accident rates. Many studies across the U.S. and Europe demonstrate that traffic congestion contributes massively to accident rates regardless of the country and year. (Wang et al, 2023; Ison,2009; Xiang,2003; Gonzezlez, 2023). This can be attributed to the fact that more collisions occur when drivers are in the compact space of traffic which leads to less room for human error to prevent collisions. (Farhad Shahla et al, 2009)

A bulk of research also showcases that human behavior impacts accident rates as well. Factors such as excessive speeding, alcohol and drug usage, sleep deprivation and distractions increase accident rates. (CDC, 2023) (NHTSA,2020) (Higgens et al, 2017). Previous studies suggest that even behavioral factors such as stressful work conditions and irritability with one's job contribute to the probability of accidents. (Cendales et al, 2017) (Cartwright et al, 1996)Another interpersonal variable that research suggests affects accident rates is the socioeconomic status of the area and the individual. Previous research displays that less affluent individuals and areas are more likely to have higher rates of accidents. (Fournier et al, 2012) This is attributed to multiple factors. Firstly, lower-income individuals are more likely to drive older, and more shoddly made cars due to their lack of resources, leading to an increased likelihood of getting into an accident and for the accident to be fatal. (Charters, Harper, Strumpf 2015) Secondly, low socioeconomic areas likely have lax road maintenance and underdeveloped roads, leading to more accidents. (Fournier et al, 2023). Lastly, individuals in low socioeconomic areas or who are less affluent may engage in more risky driving behavior overall, which could also lead to more accidents. (Charters, Harper, Strumpf 2015)

A plethora of literature also exists on the impacts high rates of accidents may have on a community that may give urgency to why the East End ought to focus on accident rates. Past studies report deaths and injuries from road traffic crashes affect medium- and long-term growth prospects by removing prime-age adults from the workforce and reducing productivity due to the burden of injuries (World Bank, 2018). Using detailed data on deaths and economic indicators from 135 countries, the study estimates that, on average, a 10% reduction in road traffic deaths raises per capita real GDP by 3.6% over a 24-year horizon. Due to this, the East End/ the city of Houston ought to invest resources on the diversion of road accidents.

For what the literature says on methods on how to examine accident and injury rates two distinct methods and tools are utilized. Past literature has utilized GIS in research on accident rates as it allows for visualization of where accidents occur and can help distinguish if certain areas have a disproportionate cluster of accidents. (Chao, 2023) Furthermore, GIS can be utilized to overlay other variables on a geographical map with accidents to spot correlations. Secondly, researchers employ negative binomial models to study accident rates. They can predict the probability of certain variables affecting overall rates of accidents. (Greibe, 2003)

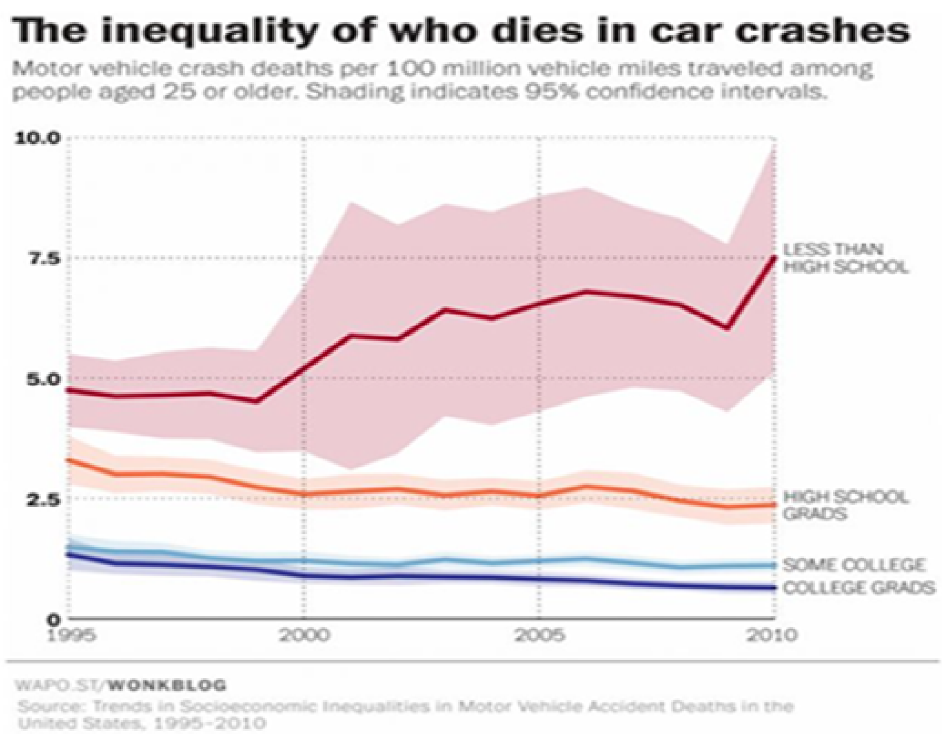
3 Motivation

In 2021, there were 331 total fatalities and 1,620 serious injuries on Houston's streets (City of Houston, 2021). This means nearly every day, someone loses their life, and close to five people every day suffer a serious injury in a traffic crash on Houston streets. During the last four years, the number of traffic deaths and serious injuries increased by an average of 18% each year (City of Houston, 2021).

A study on social inequalities in road traffic injuries found that "road users in poorer neighborhoods have a higher exposure to traffic and, traffic volume being equal, a greater risk of injury because of the presence of more major roads. . . " (Morency et al., 2012, p. 1116). Despite the independent "effect" of neighborhood socioeconomic position shown in multivariate analyses, the study suggested, "it should be underscored that poverty per se does not produce [road traffic accidents] - exposure to moving vehicles does". The association between neighborhood socioeconomic position and the number of people injured at intersections is of significant relation. While substantially lower death rates are critical, improved road safety allows everyone to enjoy healthy lives, well-being, and freedom of movement (World Economic Forum, 2022). Further afield, the Social Progress Index (SPI) – the global framework for measuring aspects of wellbeing – also credits road safety as a core measure for social progress (Social Progress, 2022), which highlights the significance of why research into road safety and how it can be improved is important. The SPI links people's sense of personal safety to the rate of road traffic deaths and ultimately deems road safety a basic human need in a successful society. In the case of Houston, the rate of road traffic accidents resulting in death is particularly high. Houston saw one of the largest increases in traffic deaths in Texas between 2020 and 2021. The number of traffic accident fatalities in the city increased from 275 in 2020 to 331 in 2021 (City of Houston, 2021). The data indicates a startling 18% jump in traffic deaths and serious injuries, and the total number of crashes was also on the rise. Their reporting shows that the number of accidents increased by 14% from 2020 to 2021.

People with lower income face higher risks of being involved in road accidents because they tend to live and work adjacent to high-risk neighborhoods with heavy traffic and poor road infrastructure (World Bank, 2018), of which the East End District's (EED) which will be discussed later in the research. Serious injuries also have long-term impacts on household incomes for low-income households. They can seriously affect the household quality of life because many are heads of households and their deaths or chronic injuries often significantly reduce family incomes (Harper et al., 2015). The most disadvantaged are more likely — and have grown even more likely over time — to die in car crashes than well-off people. New research (Harper et al., 2015) in the American Journal of Epidemiology, finds that improvements in road safety since the 1990s have led to the biggest declines in fatalities among the most educated. This is significant because studies show that "lower educational status, blue-collar or lower-status occupations and lower incomes have been associated with increased risk of traffic accident-related mortality" (Harper et al., 2015, p. 607) and this demographic also makes up a large percentage of the population of EED which has a median household income of $32,082, a high school graduate attainment rate of only 25.9% and 70% Hispanic or Latino Population (East End Chamber of Commerce, 2023). Over time, adults aged 25 and older with less than a high school diploma experience increased fatality rates. Figure 3 shows that those with less than a high school education are twice more likely to die in a car crash compared to those with high school or more education.

Figure 3: The inequality of who dies in car crashes



The chart above, based on National Center for Health Statistics data used by the researchers, captures miles traveled not just by car, but also bus or other motor vehicles. The fatalities also include the deaths of pedestrians and cyclists struck in car crashes; this is relevant to the research because those with lower incomes are also more likely to walk, cycle or use transit, while those with higher incomes often travel by private car. Thus they increase their likelihood of road traffic injury (Morency et al., 2012).

The possible effects of road accidents will greatly affect the East End (EED)as it is an area going through major economic development, with new commercial and residential buildings in the works and the attraction of more investment into the area (East End Chamber of Commerce, 2023). The issue of complex and low-visibility intersections alongside the lack of pedestrian safety can have a negative impact on the future development of the area. Road accidents can result in property damage, including damage to vehicles, buildings, and other infrastructure (National Highway Traffic Safety Administration, 2015).

Additionally, the National Highway Traffic Safety Administration highlighted in their 2015 report on the impact of crashes, and the other areas that are affected by road accidents. These include: the cost of repairing or replacing damaged property can be significant, affect the city's economy, and increase insurance costs for individuals and businesses. As the number of accidents in an area increases due to the high traffic congestion and accident rates; insurance companies may raise premiums (PWC, 2023). Tourism and the overall attractiveness of moving into the area can also be affected. The area's reputation for being unsafe due to a high number of road accidents may discourage tourists from visiting or individuals and families from relocating to the area. This can significantly impact the local economy, especially from people patronizing local businesses or hindering the new residential developments from being occupied.

4 Methodology

4.1 Data Collection

Multiple data sources were used in this report to conduct both a descriptive analysis and a regression analysis of the frequency of crashes and their severity at intersections in Harris County and, more specifically, the EED. These sources reflect the key factors that previous literature identified as integral to understanding accident frequency at urban intersections. Information about each source of data is provided below.

4.2 American Community Survey

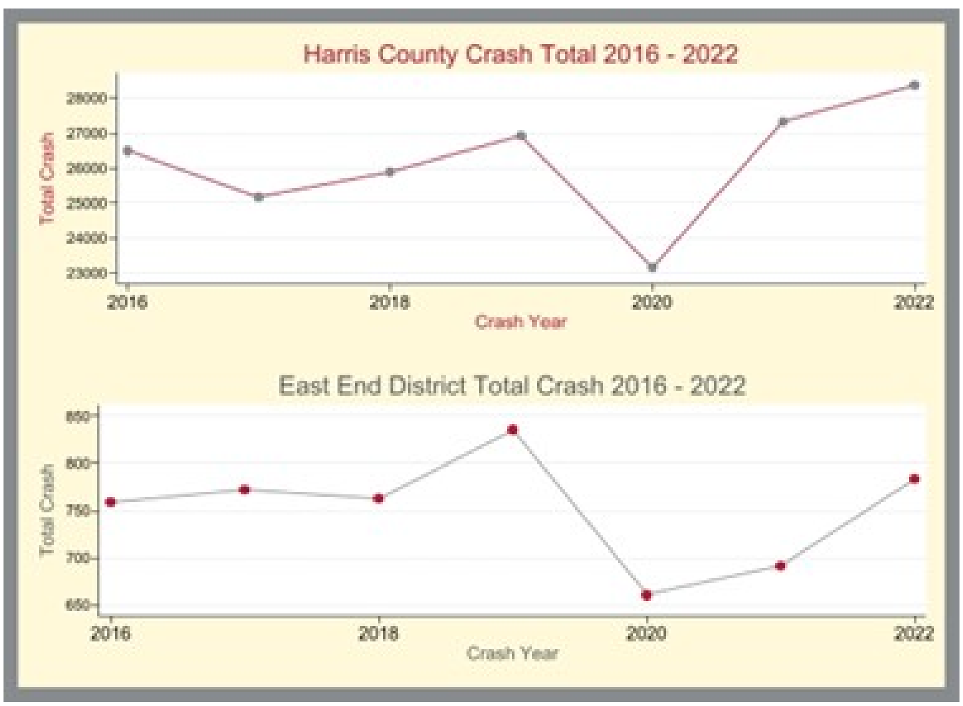
The American Community Survey (ACS) is conducted annually by the U.S. Census Bureau and provides information about a population's jobs, education, housing, and other essential indicators at different geographic levels. For this study, the 2020 five-year ACS estimates at the census tract level were used as sources of transportation data to help develop crash severity models. Specifically, the information about the percentage of people within a census tract who use different modes of transportation to work and the time it takes to commute to work. Following the example of Morency et al (2012), we used these variables as a proxy for the volume of walkers and bicyclists in a tract and if they were more likely to travel within their tract of residency or across various tracts.

4.3 TxDOT C.R.I.S. Crash Data

The Texas Department of Transportation manages the crash records information system (C.R.I.S), a public database where users can build individualized queries to analyze accidents in Texas. For this study, we created a new query to analyze the accidents in Harris County. Motivated by the Texas Transportations Institute and their study of the East End District, we narrowed our search to the following criteria.

First, we determined our years of study to be 2016 – 2022 in all of Harris County. Next, we chose intersection-related crashes with the exclusion of any accident labeled as 'INTERSTATE.' We did this to eliminate the bias when roadway characteristics of interstates are brought into our analysis of city streets and other lower-tiered arterial roadways. Interstates do not have intersections, but an accident could have received such designation because of human error in completing accident reports. Finally, we chose attributes of specific crashes we felt were relevant to our study and what previous studies have identified as essential factors in determining the frequency of specific crash types or severities. There were more than forty initial attributes selected. However, the number decreased significantly throughout the data-cleaning process. The decrease was either because the variable had too many missing observations or because it was determined that the variable was unnecessary or redundant. Figure 4 shows the total crashes for Harris County and the East End District from 2016 – 2022.

Figure 4: Harris County and East End Crashs overtime



4.4 Center for Disease Control - Social Vulnerability Index

The Center for Disease Control (C.D.C.) began producing the Social Vulnerability Index (SVI) in 2011 to help the public health community plan and assist vulnerable communities when a hazardous event occurs. Using U.S. Census Data, the C.D.C. determines the vulnerability of every census tract. They rank each tract on sixteen social factors, combined into different thematic indices of socioeconomics, housing, ethnic minority status, and transportation. They also produce an overall vulnerability that combines all themes. The percentile rankings are relative to all census tracts in the United States, which means that a census tract in the 90th percentile of vulnerability is more vulnerable than 90 percent of census tracts in the U.S. For this study, we incorporated the individual themes and the overall vulnerability rankings in Harris County and, more specifically, the EED at the census tract level. Previous literature explains that small geographic spatial zones can associate the socioeconomic characteristics of that zone with crashes in the same area (Park et al., 2015). Urban census tracts, though not small like a census block group, are typically smaller than suburban and rural tracts (Park et al., 2015). Therefore, we assume that the socioeconomic indices in the social vulnerability index can be reflected in the intersections in the spatial zones of urban areas in Harris County and the EED.

4.5 TxDOT Roadway Inventory

The Texas Department of Transportation provides open-sourced data on the roadway characteristics of all roads in Texas annually. Using the 2021 roadway characteristics of all roads in Texas, we used QGIS to join our C.R.I.S crash data spatially with the roadway characteristics of the roads involved in accidents at intersections in Harris County. Despite this, we retrieved essential variables like average annual daily traffic, number of lanes, lane width, and functional class.

4.6 Analytical Methods

Early statistical methodologies analyzing the frequency of crash data and various independent variables used linear regression models. However, with improvements in computing and continued research in the field, it was realized that linear regression models were limited in dealing with the unique nature of crash data (Khattak et al., 2021). Count models were adopted as the superior method, but those, too, are limited. Crash data is typically characterized by overdispersion – the variance of the crash data is greater than the mean. Poisson models typically used for count data assume that the variance and mean are equal. The Negative binomial (N.B.) model can overcome the overdispersion issue by allowing the variance to differ from the mean and are typically the starting point in analyzing crash data (Mahmoudi et al., 2022 (Khattak et al., 2021). Our study begins with this in mind and incorporates the N.B. model to analyze the severity of crashes at intersections in the East End District.

For our study, we ran two models at different levels of analysis using the N.B. specification. One model was conducted at the intersection level, while the other was at the census tract level. Both models have very similar dependent variables. However, the nature of the data collapsing methods to the census tract level prohibited the inclusion of the independent categorical variables. The model specifications can be found below.

$$\log(E(Y|x)) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_p x_p + \epsilon$$

where:

- log is the natural logarithm function
- $E(Y|x)$ is the expected value of the count variable Y given the explanatory variables x
- Y is the count variable
- $x_1, x_2, \ldots, x_p$ are the explanatory variables
- β_0 is the intercept, and $\beta_1, \beta_2, \ldots, \beta_p$ are the regression coefficients
- ϵ is the dispersion parameter

4.7 Crash Severity Frequency Models

Model Dependent Variables The dependent variable for our models is the count by crash severity for intersections and census tracts. For the intersection level model, we ran three regressions using different degrees of crash severity as the dependent variables. The variables are the total number of fatally injured, seriously injured, and total injuries in an accident at a given intersection in Harris County. The tract level differs in the severity of the accident used as the dependent variable. The variables include the total number of minor, serious, and fatal accidents. Notice there is no total injury count for the tract level model, but rather a minor injury count. The degree of severity is also a total count that occurred in a given census tract, broadening the scale of analysis. The number of injuries sustained in an accident at a given intersection and the total number of accidents in a given tract are both nonnegative counts, making the N.B. model an appropriate estimation given the data. Table 1 tabulates the summary statistics of the dependent variables included in our models. In the appendix, you'll find the frequency graphs at the intersection and tract level. They indicate that the majority of intersections in Harris County and the EED do not have injury accidents.

The table shows us that at the tract level, of the accidents that do cause injury, the vast majority of them are minor injury accidents. However, at the intersection level, there have been accidents in which there were three fatalities, seven serious injuries, and thirty-two total injuries.

Table 1: Dependent Variables

Variables	N	min	max	mean	sd
Census Tract Level					
Minor Injury Accident	1,111	0	303	15.523	17.966
Serious Injury Accident	1,111	0	52	3.156	3.996
Fatal Accident	1,111	0	6	0.414	0.797
Intersection Level					
Crash Death Count	179,012	0	3	0.003	0.059
Crash Suspected Serious Injury Count	179,012	0	7	0.024	0.188
Crash Total Injury Count	179,012	0	32	0.541	0.956

Independent Variables

The independent variables used in the models were chosen because of previous literatures discourse on their significance in helping determine the factors associated with various traffic accidents. Their inclusion was also determined by practicality regarding the number of missing observations and the ability to engineer them appropriately.

Fatal, Serious, and Total Injuries at the Intersection Level

The first model is at the intersection level and includes roadway, sociodemographic, and socioeconomic characteristics. Table 2 shows the descriptive statistics for the continuous variables. Tables 3 and 4 show the tabulations of the categorical and factor variables. Pairwise correlation coefficients were produced between the independent variables. The results show that there are no concerns about multicollinearity between the independent variables. The appendix table shows the pairwise correlation matrix of those variables that were statistically significant at the .05 level.

Table 2: Independent Variables

Variables	N	min	max	mean	sd
Speed Limit	173,954	5	75	37.31	6.35
Percentile Ranking for Socioeconomic Theme	178,397	0	1	.60	0.30
Percentile Ranking for Household Composition Theme	178,397	0	.99	.49	0.30
Percentile Ranking for Minority Status	178,397	0	.99	.66	0.25
Percentile Ranking for Housing/Transportation Theme	178,254	0	1	.56	0.28
Overall Percentile Ranking	178,254	0	1	.58	0.30
Car, Truck, or Van to Work	178,397	0	79	41.45	9.15
Public Transportation to Work	178,397	0	20	1.47	2.03
Bicycle to Work	178,397	0	11	.17	0.64
Walk to Work	178,397	0	38	1.51	3.56
Travel Time to Work Less Than 15 Minutes	178,397	0	44	9.03	5.51
Travel Time to Work 15 to 30 Minutes	178,397	0	45	16.41	6.18
Travel Time to Work 30 to 45 Minutes	178,397	0	34	11.80	4.54
Travel Time to Work More Than 45 Minutes	178,397	0	30	8.19	4.07
Percent (%) of Trucks in AADT	111,656	0	56	3.96	2.31
Width of Lane (ft)	111,656	4	29	10.75	2.42
Average Annual Daily Traffic (AAD)	142,210	9	320,892	22,487.77	40,405.10

Table 3: Independent Categorical Variables - Intersection Model

Number of Entering Roads			
Variables	Freq.	Percent	Cum.
Three Entering Roads - T	37,936	30.29	30.29
Three Entering Roads - Y	2,637	2.11	32.39
Four Entering Roads	82,223	65.64	98.04
5 or More Entering Roads	1,931	1.54	99.58
Other	529	0.42	100.00
Total	125,256	100.00	

Light Condition			
Variables	Freq.	Percent	Cum.
Dawn	1,443	0.81	0.81
Daylight	129,015	72.35	73.16
Dusk	1,626	0.91	74.07
Dark, Lighted	38,507	21.59	95.66
Dark, Not Lighted	6,299	3.53	99.19
Dark, Unknown Lighting	1,439	0.81	100.00
Total	178,329	100.00	

Accident Involvement			
Variables	Freq.	Percent	Cum.
Motor Vehicle	176,542	98.62	98.62
Railroad	303	0.17	98.79
Pedestrian	597	0.33	99.12
Bicycle	973	0.54	99.67
Parked Car	245	0.14	99.80
Other	352	0.20	100.00
Total	179,012	100.00	

Table 4: Independent Dummy Variables – Intersection Model

Variables	Freq.	Percent	Cum.
Signalized Intersection			
Unsignalized Intersection	105,956	59.19	59.19
Signalized Intersection	73,056	40.81	100.00
Total	179,012	100.00	
Rush Hour			
Not in Rush Hour	118,472	66.18	66.18
In Rush Hour	60,540	33.82	100.00
Total	179,012	100.00	
East End Tracts			
Not in East End District	173,848	97.12	97.12
East End District	5,164	2.88	100.00
Total	179,012	100.00	

Fatal, Serious, and Minor Injuries at the Tract Level

The second set of models is estimated at the census tract level of analysis and differs slightly in the explanatory variables than the intersection level model. The main reason for this is the method of collapsing the data set to the census tract level did not allow for an accurate interpretation or inclusion of the categorical variables. However, we did include the dummy variables. We summed each dummy variable, so each tract had a total count of when a flag was triggered. The logic behind this decision is simple. For example, a census tract with a higher number of railroad flags indicates more accidents involving railroads in that tract. Through this type of summation, we can conclude that some tracts have more accidents involving railroads or are during rush hour, or are at unsignalized intersections relative to other tracts. Table 9 shows the summary statistics for the independent variables at the tract level of analysis.

Pairwise correlation coefficients were computed using Stata to analyze the correlations between all independent variables. The results showed a high positive correlation and significant relationships between accidents during rush hour and the presence of a traffic signal – 91%, significant at the .05 level. For this reason, those two variables should remain from being simultaneously included in the regression models. No other pairwise correlations that were statistically significant were correlated above 70%. The appendix table shows the pairwise correlation matrix.

Table 5: Independent Variables – Tract Level

Variables	N	min	max	mean	sd
Overall Percentile Ranking	1,105	0	1	0.55	0.31
Transportation to Work - Bicycle	1,107	0	11	0.17	0.78
% of Trucks in AADT	1,107	2.06	16	3.90	1.42
Transportation to Work - Public Transportation (all)	1,107	0	20	1.34	2.02
Width of Lane (ft)	1,107	5.50	21	10.63	1.42
Travel Time to Work More Than 45 Minutes	1,107	0	30	8.54	4.45
Travel Time to Work 30 to 45 Minutes	1,107	0	34	11.96	4.70
Transportation to Work - Walked	1,107	0	38	0.85	2.10
Travel Time to Work Less Than 15 Minutes	1,107	0	44	8.26	4.80
Tavel Time to Work 15 to 30 Minutes	1,107	0	45	16.22	6.31
Railroad Involved	1,111	0	79	0.41	3.32
Transportation to Work - Car Truck or Van	1,107	0	79	41.78	8.76
Rush Hour	1,111	0	1,415	54.49	62.86
Signalized Intersection	1,111	0	3,156	65.76	125.44
Average Annual Daily Traffic	1,110	89	161,565.88	17,940.35	21,663.44

Table 6: Independent Dummy Variables – Tract Model: East End Tracts

District	**Freq.**	**Percent**	**Cum.**
Not in East End District	1087	97.84%	97.84%
In East End District	24	2.16%	100.00%
Total	**1111**	**100.00%**	

4.8 Descriptive Analysis

Aside from statistical analysis, the data offers an opportunity to provide a descriptive spatial analysis of accidents at intersections in the East End District to help paint a picture of problematic areas related to all road users. Though the East End only accounts for roughly three percent of all intersection-related crashes in Harris County, one goal as the East End develops and grows is to implement roadway safety measures that prevent more severe accidents that typically grow in tandem with more dense housing and increased traffic flows. This section analyzes where more dangerous intersections are and if they are associated with more vulnerable areas. It is important to note that we cannot determine if the vulnerability is necessarily a cause of accidents or if vulnerable populations are the victims of these accidents. At the very least, however, we can determine that vulnerable populations live next to and amongst hazardous roadways, which may increase the probability of being involved in an accident that results in injury.

Figure 5: Minor, Serious, and Fatal Intersection Accidents in the East End District 2016 – 2022

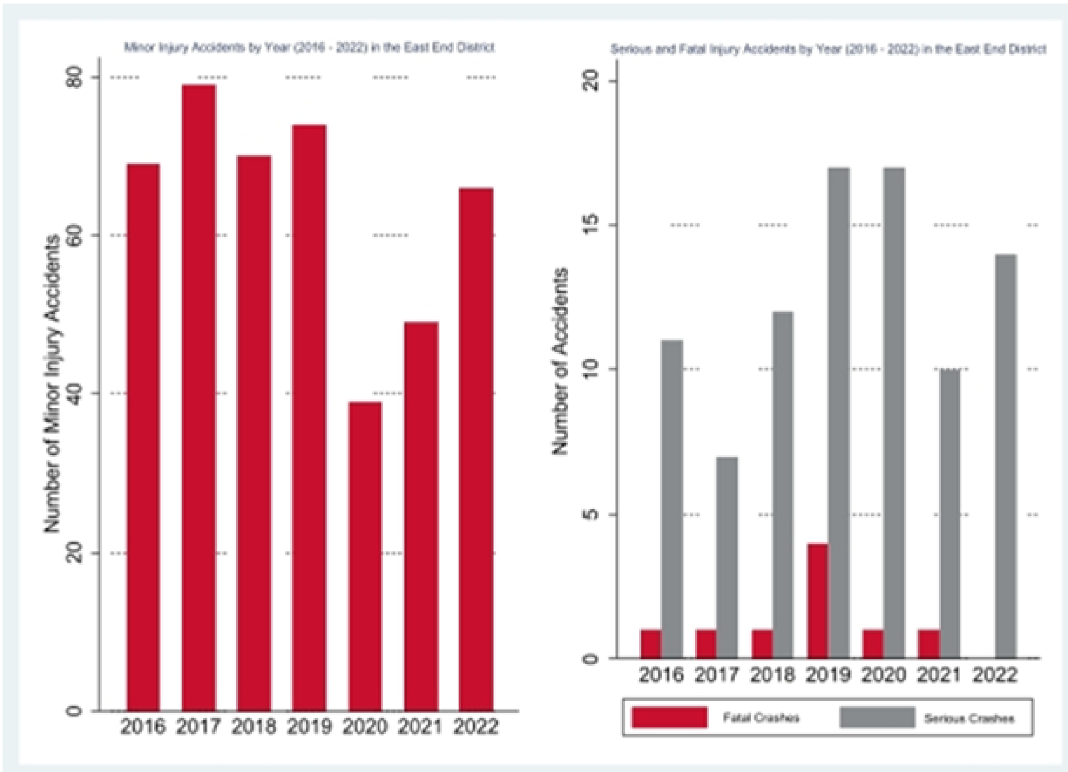


Figure 6: Minor, Serious, and Fatal Intersection Accidents in the East End District 2016 – 2022

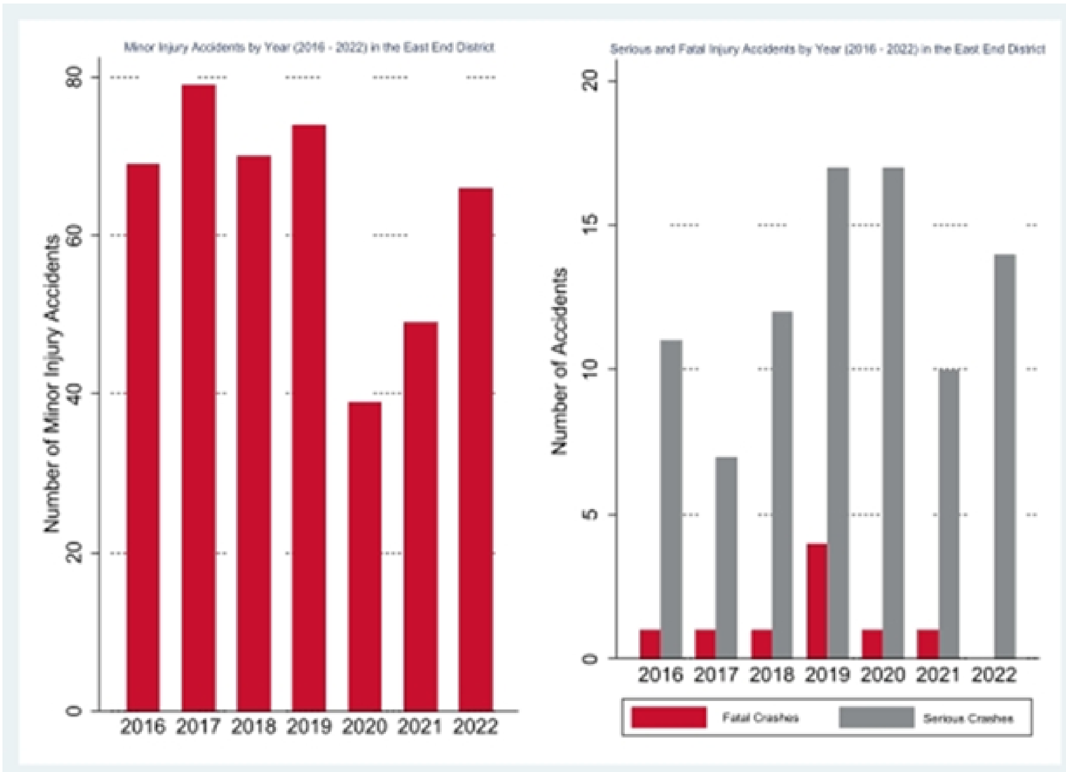


Figure 5 shows the severity of accidents in the East End District from 2016 – 2022, while Figure 6 shows all of Harris County. Before the coronavirus pandemic, severe and minor injury accidents were rising in the East End. All of Harris County experienced decreased minor injury accidents at intersections, which has since exceeded pre-pandemic levels. Regarding severe and fatal accidents, Harris County is trending in the wrong direction, and the East End does not want to follow that trend. However, since 2020, the East End has seen dramatic increases in severe and minor injury accidents. There could be an adjustment back to the mean following the pandemic. Still, given the expected growth in the East End, policymakers should be aware of a possible spike in traffic-related injuries.

Figure 7: Minor, Serious, and Fatal Intersection Accidents in Harris County 2016 – 2022

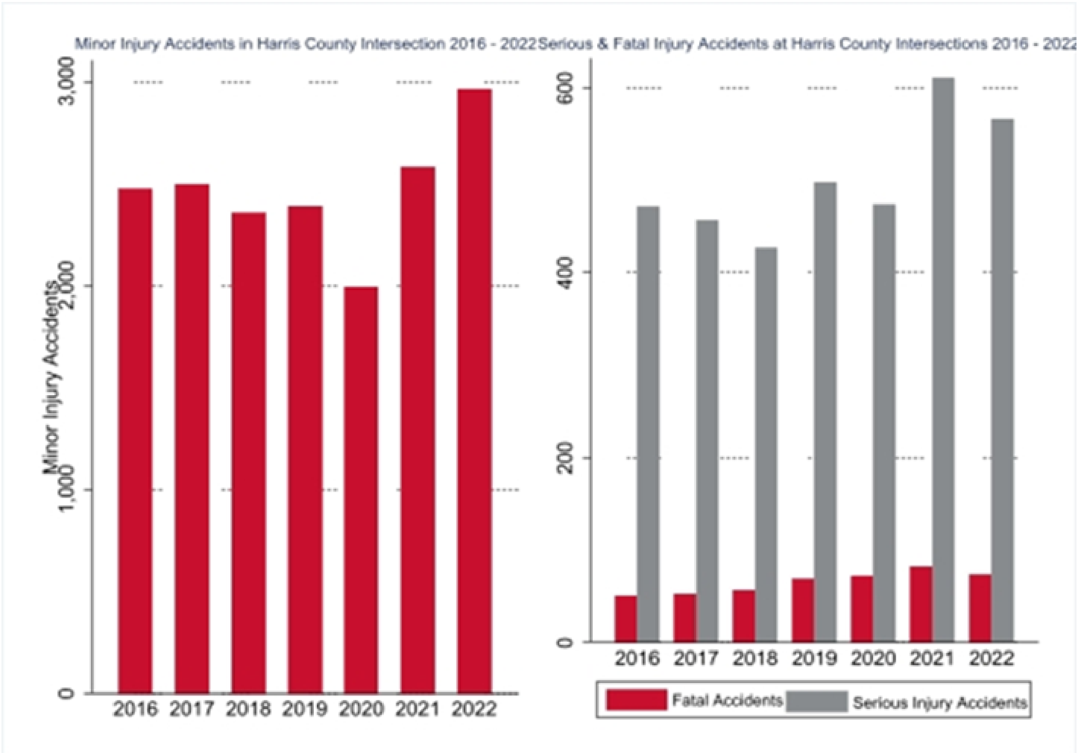


Figure 8: Accident Involvement at Intersections in the East End District 2016 – 2022

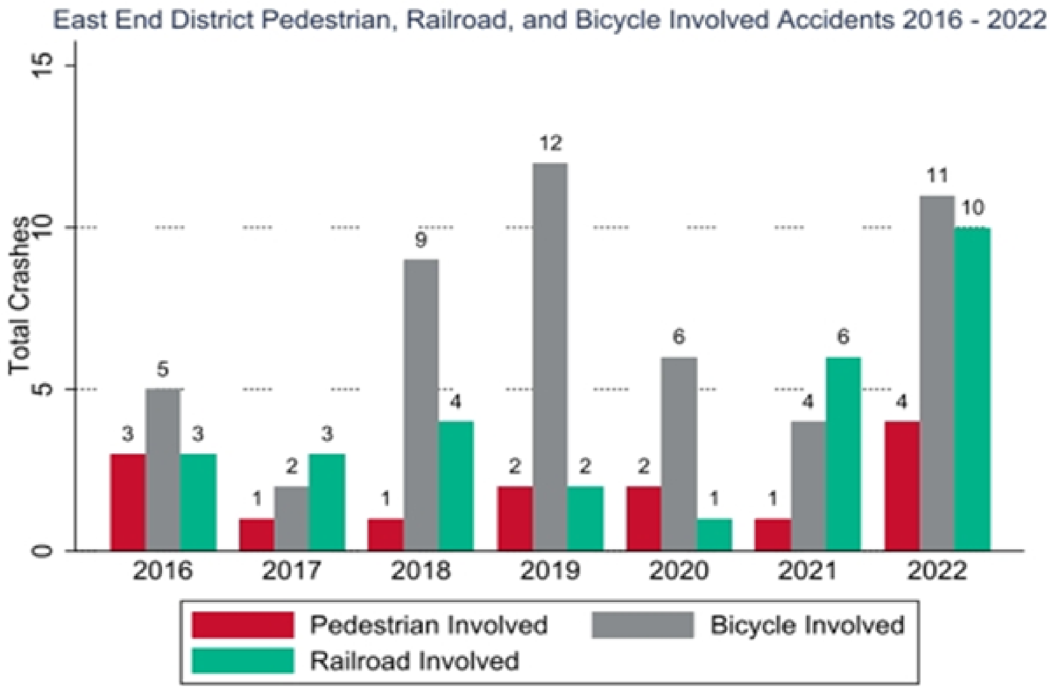
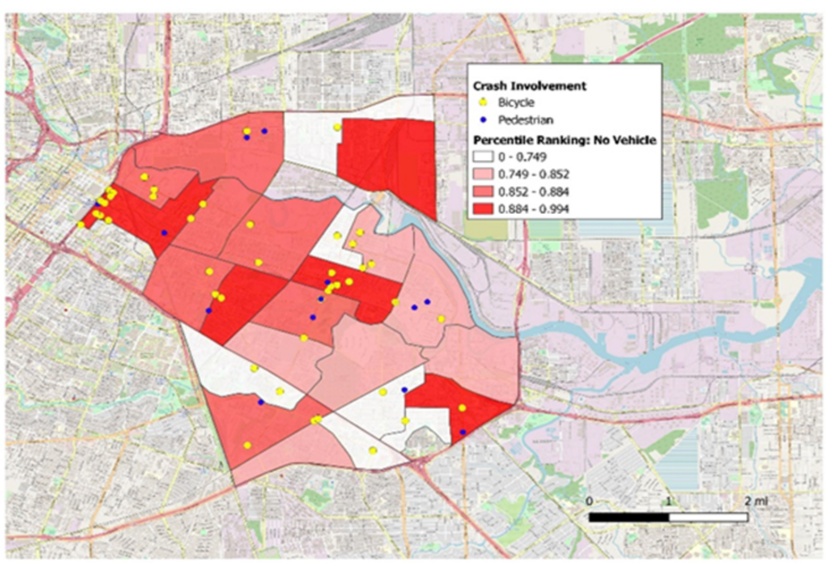


Figure 9: Pedestrian and Bicycle Involved Accidents by Percentile Ranking with No Vehicle Access at Intersections the East End District



Vulnerable road users like pedestrians and bicyclists are also a concern in the East End district as it not only has access to alternative modes of transportation, but the current growth resembles that of a walkable city - connectivity, density, safety, and proximity to amenities and public spaces. Figure 7 shows the number of accidents that vulnerable road users have been involved in from 2016 – 2022 in the East End district. Pre-pandemic bicycle accidents were on the rise and have returned to that level. In addition, there have been fluctuations in pedestrian-involved accidents; however, 2022 saw the most since 2016. Therefore, one necessary component to help policymakers solve the problem of preventable injuries and deaths on roadways is to identify areas where most injuries and accidents occur

Figure 10: Accident Involvement at Intersections in the East End District 2016 – 2022

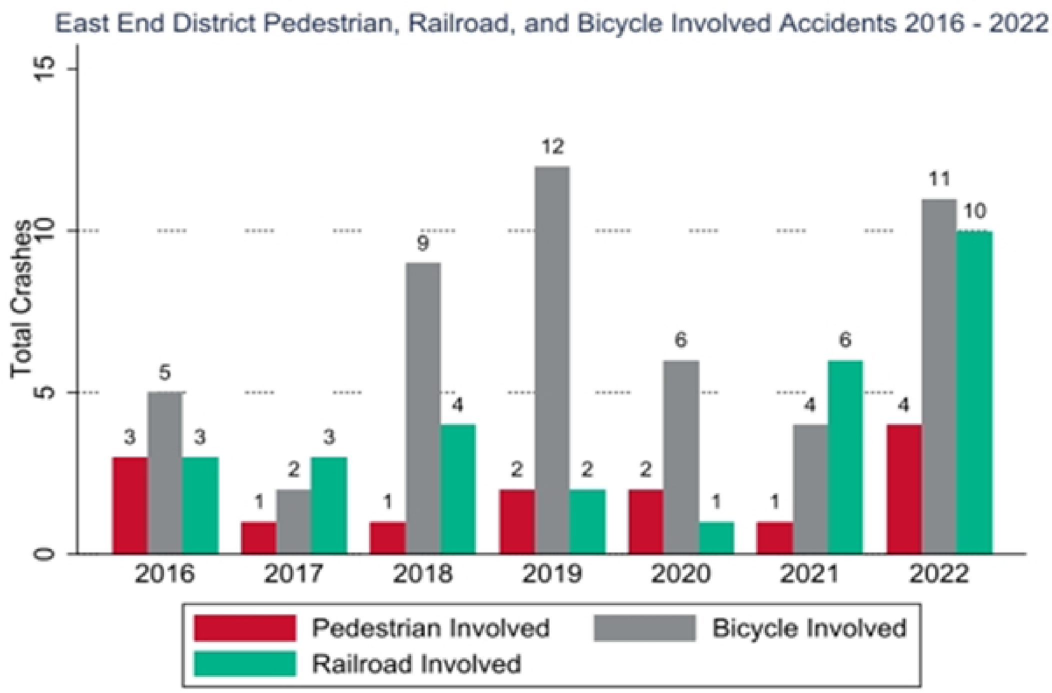


Figure 11: Pedestrian and Bicycle Involved Accidents by Percentile Ranking with No Vehicle Access at Intersections the East End District

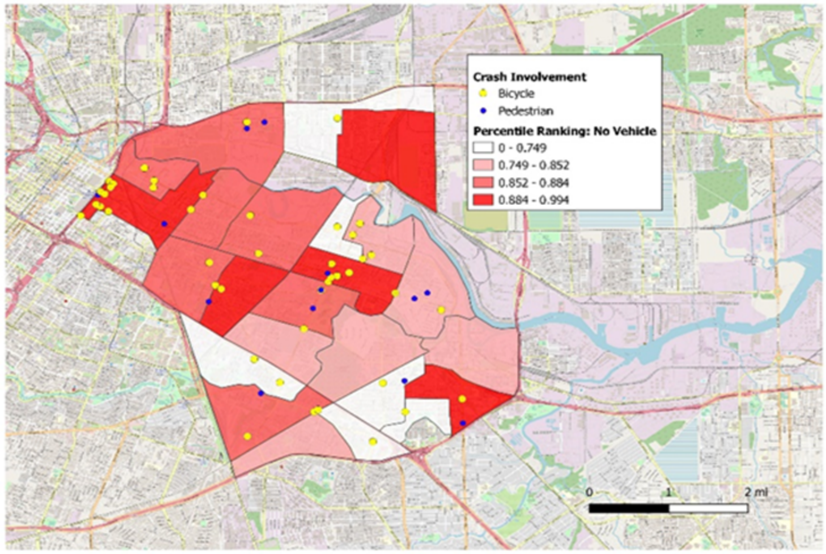


Figure 8 shows the intersections where bicycles and of pedestrians are involved in accidents. They overlay the SVI ranking of those with access to no vehicle. A striking association exists between more vulnerable areas and accidents at intersections involving bicyclists and pedestrians, suggesting that those populations do not have access to infrastructure that allows them the same safety as those in vehicles. Consistent with previous literature, without traffic calming measures or roadway amenities like bike routes or raised medians, these vulnerable road users will continue to be at risk.

Figure 12: Serious Injury Accidents by Percentile Ranking with No Vehicle Access at Intersections in the East End District

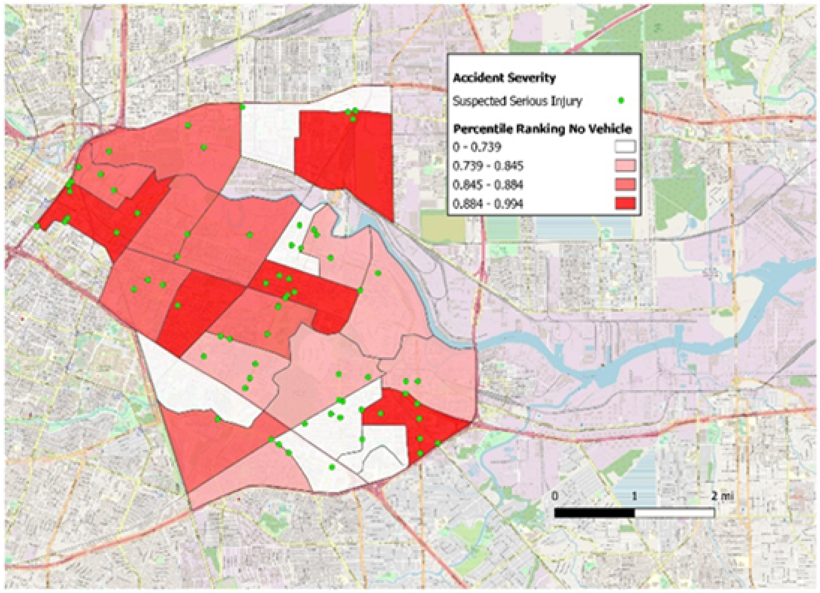
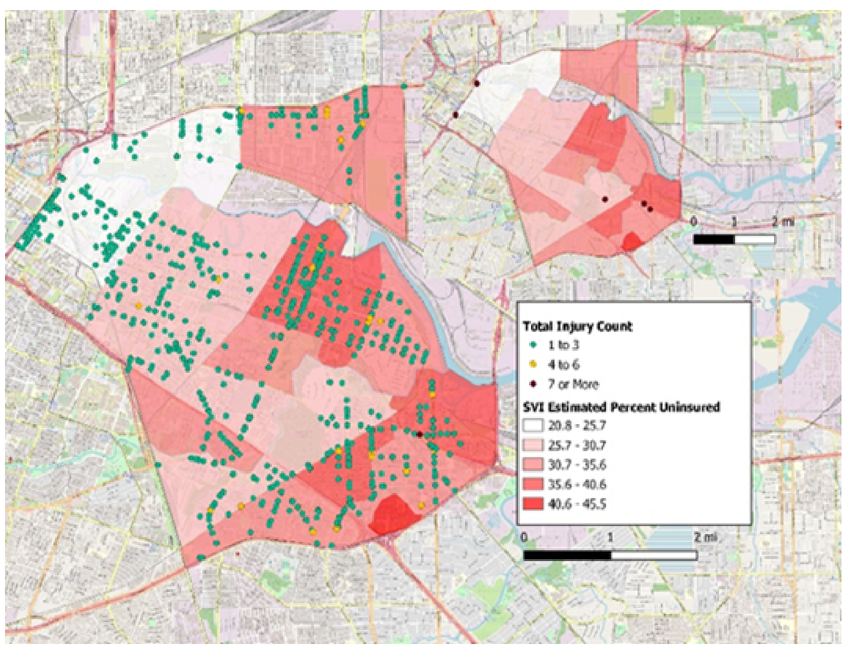


Figure 13: Total Injury Count by Percentile Ranking with No Vehicle Access at Intersections in the East End District



Serious injuries also occur in the same areas with clusters of pedestrian and bicycle accidents. Identifying these locations could improve outcomes for those living, working, and playing in the East End District. Figure 9 shows the locations of accidents where serious injuries occurred. There are clusters on the district's west end, central regions, and southeast.

You will also notice that these areas are vulnerable regarding access to personal transportation. For example, serious accidents happen on Chartres Street between Polk Street to the south and Runnel Street to the north, along I-69. Similar clusters occur along Wayside Drive from Lawndale Street to the south and Navigation Blvd north. Severe injuries are a cause for concern, but for vulnerable communities, any injury and a potential encounter with the healthcare system can be devastating

Figure 10 shows intersections by total injuries at that intersection. This map is valuable for policymakers in identifying dangerous intersections. The intersections with seven or more injuries include Lawndale Street, Fennell Street, and the La Porte Freeway. Not too far from that location is the intersection of Broadway Street and the La Porte Freeway. Both locations are on the southeast side of the district, where uninsured populations are between thirty and forty percent. These intersections have large amounts of traffic volume in common and four or more legs or entrances into the intersection.

Lawndale has another location to the west, where it crosses Lawndale Plaza and Redwood Street. These intersections are where Lawndale moves from a divided four-lane road to an undivided four-lane road. Again, abrupt changes in the roadway geometry or complicated transitions could be a potential reason for more total injuries.

The other two locations where multiple injuries occur are on the district's west side along Chartres Street. Though this location is not as vulnerable regarding insurance coverage or socioeconomic status, it is an excellent example of how we can meet the needs of all road users in the East End.

5 Results

Table 7 in the appendix showcases regression results at the intersection level. To interpret these results we will utilize an equation which we will call the exponential equation to convert our coefficients to percent change of how they affect Y. The equation is as follows.

$$100(\mathrm{e}^{\beta} - 1) \tag{1}$$

For the East End specifically, we can see that it statistically significantly has less severe injuries than non-east end districts. Meaning that, if the accident occurs in the East End, the accident is less likely to be serious compared to other areas. This could be due to the fact, that since the area is still developing and not as commercialized as other areas in the county, that for now it may not have high rates of accidents yet.

When examining road design results, intersections with four and more and five and more entry roads are statistically significant in regards to their impact on serious injury counts, and total injury counts. This is consistent with previous literature that attributes increases in accidents and injuries to multiple entries into intersections.(Samyajit Basu et al,2022;Kai, Wang et al, 2015) Holding all other variables consistent, intersections having four or more entry roads are associated with an estimated change of .0121 in the log count of serious injury crashes and an estimated change of 0.142 in the log count of total accidents. Using our exponential equation, we can examine that four or more entry roads cause a 1.22% increase in serious injury counts and a 1.45% increase in total injury counts. For five and more entry roads, it is associated with an estimated change of .414 in the log count of serious injury crashes and an estimated change of 0.108 in the log count of total accidents. The exponential equation dictates that five or more entry roads lead to a 51.3% increase in serious injury counts and an 11.4% increase in total accidents. Road entries are not significant with death counts which can be attributed to past literature that states that intersection accidents are less fatal and severe.(Poch, Mannering 1996) This showcases that the EED should consider not implementing intersections and roads with multiple ways of entry to avoid higher rates of accidents. Furthermore, the district ought to consider redesigning intersections and roads with multiple entryways that it currently has.

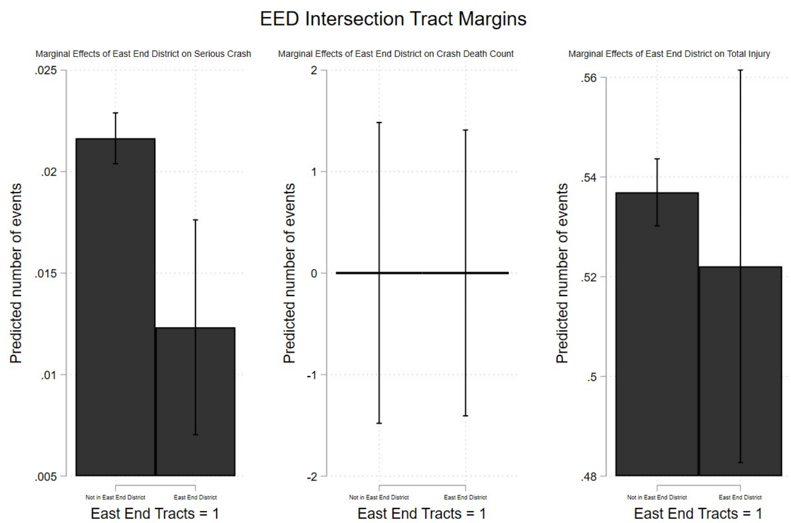
Speed limits are statistically significant across all three models. Higher speed limits have an estimated change of .0293 in the log count of serious injury crashes and an estimated change of 0.414 in the log count of deaths, and an estimated change of .0110 in the log count of total accidents. Using our exponential equation we can see that every 1 mile per hour added to the speed limit leads to an increase of 2.98% for serious injury accidents, 51.3% for crash deaths, and 1.11%. This is likely due to higher speed limits being associated with high counts of severe accidents and fatalities. (Ashenfelter, Greenstone 2004) This may provide evidence that lower speed limits ought to be implemented as the EED develops to prevent a higher number of deaths and accidents from crashes.

A signal being present may also prevent a large number of accidents as well as it has a negative statistically significant effect on total accidents. A signal being present is associated to a 9.3% in total accidents holding all else constant. This may provide evidence that for the east end to combat accidents while the east end grows is to install more signals.

One puzzling result is that rush hour seems to have a negative association with severe accidents and total accidents. While this may seem like contradictory results to the literature there are some theoretical reasons why this may be the case. Previous literature indicates that the majority of rush hour accidents happen on highways, so it could be the case that during rush hour while people drive to and from work cars may migrate more to highways instead of intersections. (Zeng, et al 2018)

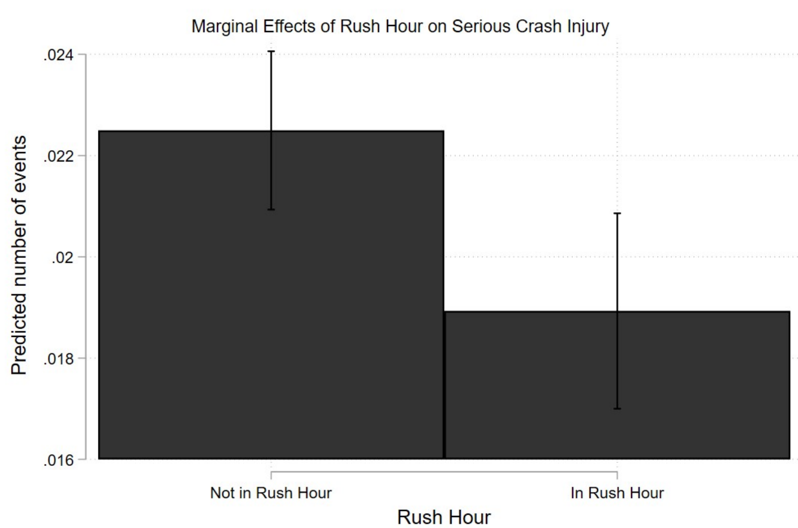
Regarding the social vulnerability index, social vulnerability is statistically significant with severe injury accidents and total accidents. Higher social mobility areas are associated with an estimated change of .259 for the log count of severe injury accidents and .279 for total accidents. The exponential equation showcases that scoring 1 point higher in the social vulnerability index results in a 29.5% increase in severe injury accidents and a 32.1% increase in total accidents. This is consistent with previous literature that claims low socioeconomic areas tend to have more overall accidents and injuries (Fournier et al, 2012).

Figure 14: EED Intersection Tract Margins



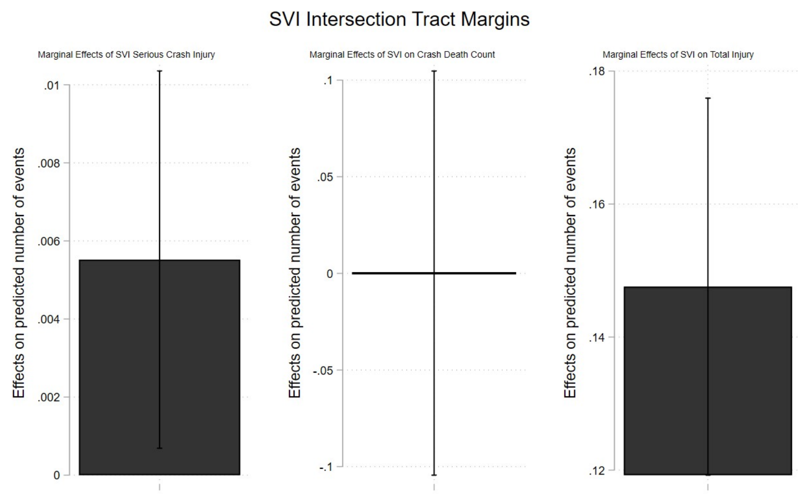
The graph above displays the marginal effect of intersections not being or being in the east-end district. Looking at the bar graphs, we can display that those insections not in the EED have a higher probability of having serious crashes, crashes that lead to death, and total injury. This displays that EED intersections have less probability of contributing to serious crashes, crash deaths, and total crashes. This may be due to the fact that even though the area is developing, it still may not be as commercialized as the rest of Harris County, and high-density areas tend to have more accidents.

Figure 15: Rush Hour Intersection Tract Margins



The margins graph above displays the marginal effect of rush hour on our dependent variables. This displays that during non-rush hours, the probability of non-rush hour crashes and death counts increases. As stated before, this could be due to a majority of rush hour accidents occurring on highways and cars migrating to them and not intersections.

Figure 16: SVI Intersection Tract Margins



The above margins graph displays the marginal effect the social vulnerability index has on our dependent variables. The marginal effect graphs display that intersections that score high on the social vulnerability index lead to a higher probability of leading to more serious and total accidents and crashes that cause death as well. This supports previous literature that states that poorer communities face higher rates of accidents and may inform the EED that improved community socioeconomic factors may help improve road safety.

5.1 Census Tract

Table 8 in the appendix shows results at the census level. The EED is not significant to any of our dependent variables in this model which may display to us that its census track specifically in the area may not differ much from the rest of Harris County.

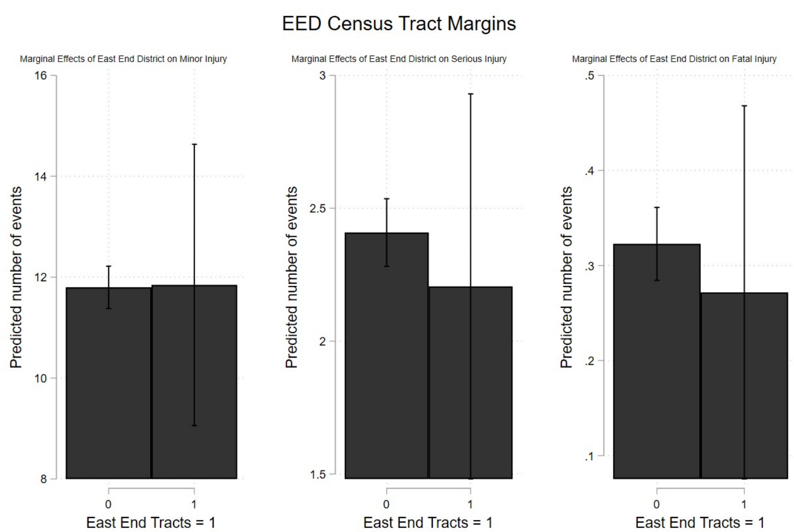
The average daily traffic is statistically significant across all the dependent variables. For every 100,000 cars minor crash severity, serious crash severity and fatal crash severity increase by 45.6%, 28%, and 78.9% respectively. This is likely due to the fact that having more cars on the road typically leads to more accidents. This ought to serve as a result of caution for the EED as the area's rapid development will likely result in more cars and traffic in the area.

The presence of railroad flags is statistically significant for each dependent variable and decreases the association of log count of crash severity.at each level. Railroad flags are associated with a 3.9% decrease in minor crash severity, a 7% in serious crash severity, and a 14.9% decrease in fatal accidents. This could be due to railroad accidents often not being as bad due to the presence of immense guardrails, and signals being present. (Elvik, 1995) This provides evidence that accidents in the EED may have less injury severity due to the immense presence of railroads in the community.

Rush hour is statistically significant for all three dependent variables which may give credence to our previous claim that rush hour previously had a negative relationship in model 1 due to it being at the intersection level, as the tract level covers more unique road types such as highways. If it's rush hour, it is associated with a percent increase of 3.9%,7%, and 14.9% in minor, serious, and fatal crash severity respectively. This is more consistent with previous literature than our previous results.

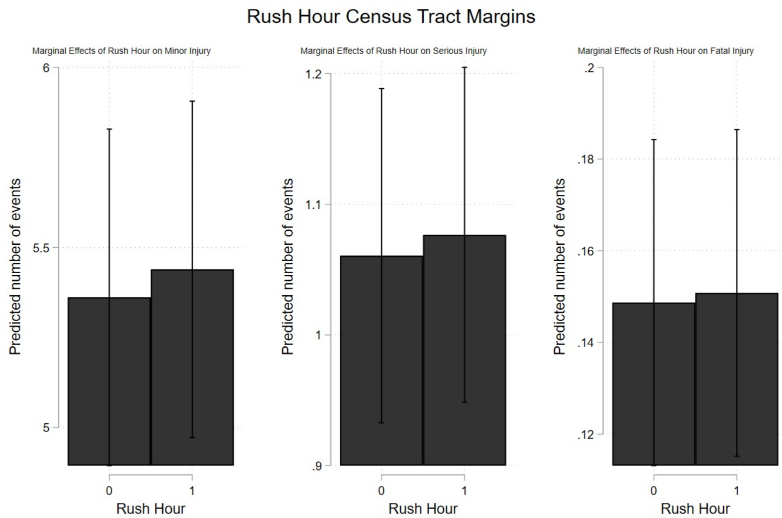
Higher SVI continues the previous trend of having a positive association with accidents as it is statistically significant for all accident types. One point higher in SVI is associated with a percent increase of 22.4%, 52.3%, and 76.6% for minor crash severity, serious crash severity, and fatal crash severity respectively. This result replicates past literature claims that low socioeconomic areas suffer more from car accidents and fatalities. (Charters, Harper, Strumpf 2015)

Figure 17: EED Census Tract Margins



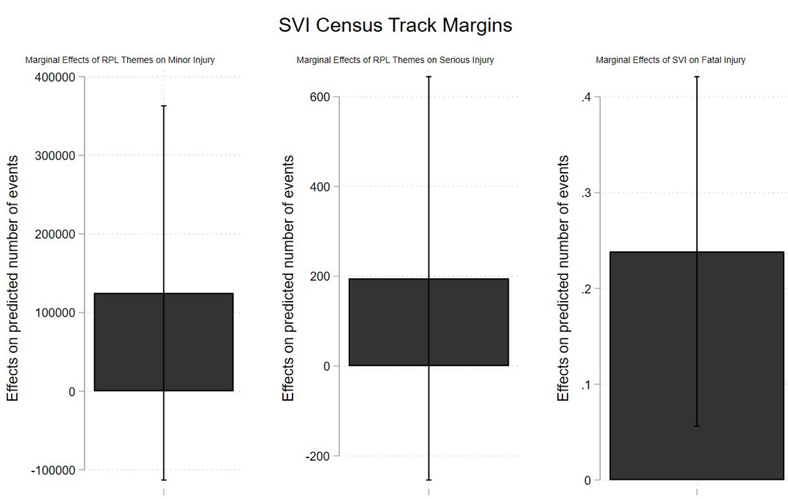
The margins plot above displays the marginal effect a tract belonging in the EED district or not affect crash severity variables. This graph displays that a tract belonging to the EED slightly increases the probability of a minor injury crash occurring but decreases the probability of a serious or fatal crash occurring. This could be due to the fact that the EED is a still developing district that has some confusing roads/intersections. So the road design may cause some minor injury accidents, but the area does not have the highways or high-speed limits to cause more serious and fatal accidents currently.

Figure 18: Rush Hour Census Tract Margins



The margin plot graphs above display the marginal effect rush hour has on accident injury severity. Expectedly, rush hour increases the probability of all injury types of accidents occurring. This is due to rush hour generally causing more traffic congestion that leads to more overall accidents.

Figure 19: Rush Hour Census Tract Margins



The above graph displays the effect SVI has on crash injury types. At all three levels, we can see that higher levels of social vulnerability tract areas increase the chances of all three injury crashes occurring. This further validates previous claims of lower socioeconomic areas containing more crashes, accidents, and more severe injuries. (Charters, Harper, Strumpf

2015;(Fournier et al, 2023)

6 Policy Implications

Roadway environment can explain a substantial portion of the excess rate of road traffic injuries in the poorest urban areas (Morency et al., 2012), considering this finding and its relevance to the East End District (EED) in Houston as explored in previous sections; there are many policy implications that arise from this. Policies that focus on improving road safety could be directly related to increasing the quality of life for residents in these affected areas. Road deaths remain a major public health burden, with approximately 40,000 road deaths annually in the United States (Morency et al., 2012), therefore policies that address road safety issues also provide solutions to a major public health issue. Many road traffic accidents are preventable, and research has shown that implementing evidence-based policies and interventions can reduce the incidence and severity of crashes (Centers for Disease Control and Prevention, 2021).

Firstly, policies that improve road safety, including the implementation of traffic calming measures e.g. speed humps and roundabouts, road signs, and traffic lights, can help to reduce the incidence of accidents. The addition of speed humps in conjunction with speed limits, can reduce road traffic injuries by 53% to 60% (Tester et al., 2004). It has been found that children who live within a block of a speed hump had significantly lower odds of being struck and injured by an automobile in their neighborhood (Tester et al., 2004). This addition to the EED would be suitable mainly for smaller roads with two-way lanes. This could not only reduce the severity but also the number of crashes as it would obligate drivers to slow down whilst on roads with high pedestrian and cycling traffic but also impose a moment to slow down and think before engaging with the complex intersection. As mentioned above, roads within the EED that have four or more entryways have a statistically higher impact on the severity of road traffic injuries. Therefore a policy recommendation of speed cameras and stricter enforcement would be best suited for those roads. Although not common in the Houston area, roundabouts are effective in speed management because this circular intersection safely moves traffic and significantly calms traffic. Studies have shown roundabouts can lower speeds by as much as 15 to 20 mph and reduce severe crashes by nearly 80 percent (Federal Highway Administration, 2023), again this traffic calming strategy only works for smaller roads in the EED.

An additional policy area to consider would be the uplifting and investment in the communities most affected. Lower income communities are more vulnerable to the economic and social consequences of road traffic accidents, including loss of income and decreased quality of life. Those in the local communities who are socially vulnerable and more likely to be involved in road traffic accidents such as those in the EED would benefit from policies that invest in new road safety plans that include wider sidewalks and diverting the amount of traffic going through these neighborhoods. Policies that provide social protection, including financial assistance, rehabilitation services, and support for victims of trauma, can help to mitigate the impact of accidents on these communities. The feasibility of this would have to be further researched, as of now there is no local or state funding for victims of road traffic accidents outside of the insurance coverage claimed.

Furthermore, a policy area that would not only alleviate the effects of road traffic accidents but also revitalize the city as a whole, is investing in an effective public transport system that encourages people to drive less. Houston as a whole is known as a "car centric" city (City of Houston, 2021) but with changing times this cannot continue in terms of both sustainability and the rate of road traffic injuries. The EED is still in stages of new development, with residential and commercial investments increasing (East End Chamber of Commerce, 2023), an effective and efficient public transportation system that includes frequent buses etc. could be used for Houston as a whole that this is a system that is not only safer for all but less costly for the local authorities as the rate of incidents will decline and the secondary effects of less pollution in a city that has worryingly high air pollution levels (National Resources Defense Council, 2021).

7 Conculsion

7.1 Limitations of Study and Methods

Our study of intersection-related accidents in the East End District and Harris County has a few limitations that can be addressed in future research.

First, we were limited in our access to data. Previous literature like Mahmoudi et al. (2022) cites attributes of land use and the built environment that we could not incorporate into our study. This exclusion is significant because areas in the EED may be more prone to pedestrian and bicycle accidents because they either have a higher density of businesses that attract pedestrians and bicyclists or because of a higher density of intersections. Understanding how the built environment relates to the frequency of accidents can help policymakers as the area grows into a more dense, multimodal area of transportation and living. Similarly, the roadway characteristics retrieved from the TxDot roadway inventory were missing data for over ninety-five percent of the observed accidents at intersections. Because of this, we had to drop some variables that may have helped us understand intersections in the EED and Harris County. Some pertinent variables that would have been beneficial to include were the median type, the number of lanes that included turn lanes, and the shoulder uses (bike lanes, parking, etc.).

Lastly, future research on the East End may benefit from multiple models that can account for a large number of zeros in the data. For example, histograms for our dependent variables show that more than ninety percent are zero. For this reason, a zero-inflated or zero-inflated negative binomial model should be estimated and compared alongside the negative binomial model.

Nonetheless, we are confident that the results of our study can help guide policymakers and stakeholders in the East End regarding the safety and mobility of vulnerable road users. As the East End grows, all community members must be considered, valued, and present in the built environment.

Nonetheless, the results of this study show the severity of road traffic accidents and highlight a need for a greater focus on reducing not only the severity but also the frequency of these accidents. Policymakers and stakeholders within the East End District can use this research to further understand the road design needs of this area. In order to ensure that the future of the East End District does not develop in a similar way to the other areas of Harris County. Residents and visitors of the East End District should feel confident that their safety is prioritized whilst using the roads and sidewalks and this can only be achieved through a carefully developed approach that encompasses the needs of the socially vulnerable communities along with those who are investing in the future of the East End District.

Acknowledgments

As our time at the Hobby School comes to a close it is important for us to give thanks to those who were integral to our success on our journey to graduation. First, we would like to thank the Hobby School and Dr. Buttorf for the continued support and guidance throughout our time in the program. Next, we would like to express our gratitude to the East End District and Jack Hanagriff for the opportunity to display what we have learned in the Hobby School program and to help the citizens of Houston. Lastly, but definitely not least, we extend our thanks and gratitude to our family and friends who have supported us and sacrificed so that we could continue our educational journey.

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8 Appendix

Figure 20: Pairwise Correlation Matrix - Intersection Level IV's

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
(1) Average Annual Daily Traffic	1.00																		
(2) % of Trucks in AADT	0.21*	1.00																	
	(0.00)																		
(3) Lane Width (ft)	0.04*	0.02*	1.00																
	(0.00)	(0.00)																	
(4) Speed Limit	0.30*	0.17*	-0.07*	1.00															
	(0.00)	(0.00)	(0.00)																
(5) Number of Entering Roads	0.02*	-0.01*	0.04*	-0.07*	1.00														
	(0.00)	(0.00)	(0.00)	(0.00)															
(6) In East End District	-0.05*	0.02*		-0.09*	0.02*	1.00													
	(0.00)	(0.00)	(0.34)	(0.00)	(0.00)														
(7) Light Condition	0.02*			0.03*	0.01*	-0.01*	1.00												
	(0.00)	(0.68)	(0.26)	(0.00)	(0.00)	(0.00)													
(8) Accident Involvement	-0.03*	-0.01*		-0.06*	-0.04*	0.01*	0.03*	1.00											
	(0.00)	(0.00)	(0.62)	(0.00)	(0.00)	(0.00)	(0.00)												
(9) Signalized Intersection	0.16*	0.04*	0.03*	0.16*	0.20*	-0.03*	0.05*	-0.03*	1.00										
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)											
(10) Rush Hour	-0.03*	-0.01*	-0.01*	-0.03*	-0.04*	0.01*	-0.23*		-0.08*	1.00									
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.11)	(0.00)										
(11) Total SVI Percentile	0.07*	0.07*	-0.08*	0.03*	-0.01*	0.10*	0.03*		-0.05*	-0.01*	1.00								
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.10)	(0.00)	(0.00)									
(12) Car, Truck, Van to Work	0.02*	-0.03*	0.08*	0.01*	-0.01*	0.02*		-0.01*	0.02*		-0.49*	1.00							
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.16)	(0.01)	(0.00)	(0.46)	(0.00)								
(13) Public Transportation to Work	-0.05*	-0.08*	0.09*	-0.19*	0.07*	0.05*	0.01*	0.01*	0.02*	-0.01*	0.04*	-0.04*	1.00						
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)							
(14) Bicycle to Work	-0.06*	-0.05*	0.07*	-0.12*	0.05*	-0.03*	-0.01*	0.01*	0.02*	0.01*	-0.16*		0.18*	1.00					
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.19)	(0.00)						
(15) Walk to Work	-0.11*	-0.06*	0.11*	-0.21*	0.11*	0.02*	0.01*	0.01*	0.12*	-0.01*	-0.22*	-0.07*	0.25*	0.26*	1.00				
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)					
(16) <15 Min to Work	-0.07*	-0.04*	0.13*	-0.20*	0.10*	0.08*	-0.01*		0.08*		-0.32*	0.35*	0.20*	0.26*	0.58*	1.00			
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.10)	(0.00)	(0.26)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)				
(17) 15 – 30 Mins to Work	-0.01*	-0.08*	0.12*	-0.18*	0.08*	0.01*	-0.01*		0.05*	-0.01*	-0.39*	0.56*	0.24*	0.24*	0.28*	0.36*	1.00		
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.63)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)			
(18) 30 – 45 Mins to Work		-0.01*	0.03*	0.02*	-0.02*	-0.02*	0.02*	-0.00*	-0.01*		-0.12*	0.49*	0.06*	-0.06*	-0.05*	-0.11*	0.02*	1.00	
	(0.73)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.05)	(0.00)	(0.43)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)		
(19) >45 Mins to Work	0.03*	0.01*	-0.07*	0.23*	-0.10*	-0.03*	0.03*	-0.01*			-0.08*	0.21*	-0.04*	-0.19*	-0.18*	-0.26*	-0.33*	0.11*	1.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)	(0.11)	(0.88)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	
*** p<0.01, ** p<0.05, * p<0.1																			

Figure 21: Pairwise Correlation Matrix - Tract Level IV's

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(1) Average Annual Daily Traffic	1.00															
(2) % of Trucks in AADT		1.00														
	(0.85)															
(3) Lane Width (ft)			1.00													
	(0.76)	(0.64)														
(4) Rush Hour	0.13*			1.00												
	(0.00)	(0.39)	(0.32)													
(5) Signalized Intersection	0.17*			0.91*	1.00											
	(0.00)	(0.47)	(0.32)	(0.00)												
(6) Railroad-Involved Accident				0.66*	0.70*	1.00										
	(0.21)	(0.48)	(0.11)	(0.00)	(0.00)											
(7) Total SVI Percentile		0.07*	-0.07*	0.07*			1.00									
	(0.50)	(0.02)	(0.02)	(0.01)	(0.55)	(0.56)										
(8) Car, Truck, Van to Work	0.06*		0.12*				-0.44*	1.00								
	(0.04)	(0.17)	(0.00)	(0.31)	(0.84)	(0.25)	(0.00)									
(9) Public Transportation to Work		-0.08*	0.06*			0.13*	0.15*	-0.10*	1.00							
	(0.56)	(0.01)	(0.04)	(0.14)	(0.11)	(0.00)	(0.00)	(0.00)								
(10) Bicycle to Work							-0.08*		0.20*	1.00						
	(0.20)	(0.10)	(0.29)	(0.77)	(0.64)	(0.06)	(0.01)	(0.23)	(0.00)							
(11) Walk to Work			0.07*	0.25*	0.29*	0.31*		-0.11*	0.12*	0.19*	1.00					
	(0.52)	(1.00)	(0.03)	(0.00)	(0.00)	(0.00)	(0.06)	(0.00)	(0.00)	(0.00)						
(12) <15 Min to Work			0.10*	0.13*	0.14*	0.15*	-0.20*	0.34*		0.22*	0.44*	1.00				
	(0.12)	(0.24)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.22)	(0.00)	(0.00)					
(13) 15 – 30 Mins to Work		-0.09*	0.16*				-0.28*	0.56*	0.19*	0.17*	0.21*	0.29*	1.00			
	(0.30)	(0.00)	(0.00)	(0.61)	(0.13)	(0.33)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)				
(14) 30 – 45 Mins to Work								0.42*	0.08*		-0.08*	-0.17*		1.00		
	(0.95)	(0.65)	(0.17)	(0.35)	(0.44)	(0.75)	(0.33)	(0.00)	(0.01)	(0.47)	(0.01)	(0.00)	(0.37)			
(15) >45 Mins to Work			-0.07*	-0.07*			-0.13*	0.19*		-0.16*	-0.18*	-0.27*	-0.34*		1.00	
	(0.60)	(0.68)	(0.02)	(0.02)	(0.15)	(0.05)	(0.00)	(0.00)	(0.36)	(0.00)	(0.00)	(0.00)	(0.00)	(0.18)		
(16) East End Tract		0.08*				0.06*	0.14*									1.00
	(0.13)	(0.01)	(0.85)	(0.09)	(0.98)	(0.03)	(0.00)	(0.10)	(0.36)	(0.41)	(0.40)	(0.67)	(0.74)	(0.17)	(0.15)	
*** p<0.01, ** p<0.05, * p<0.1																

Figure 22: Frequency of Dependent Variables at Intersection Level

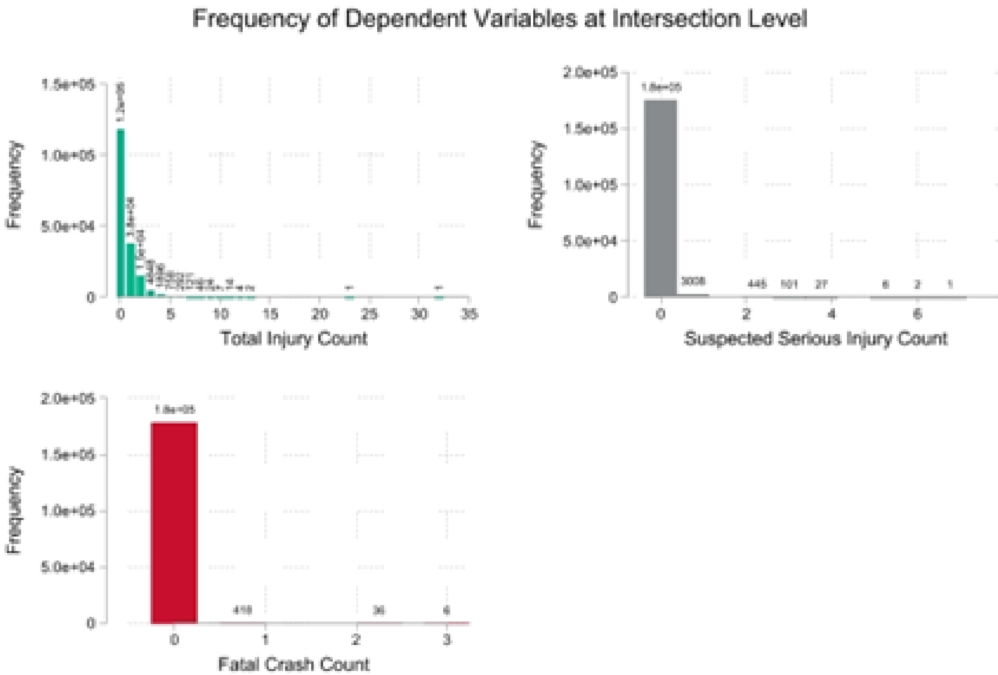

Figure 23: Frequency of Dependent Variables at Tract Level

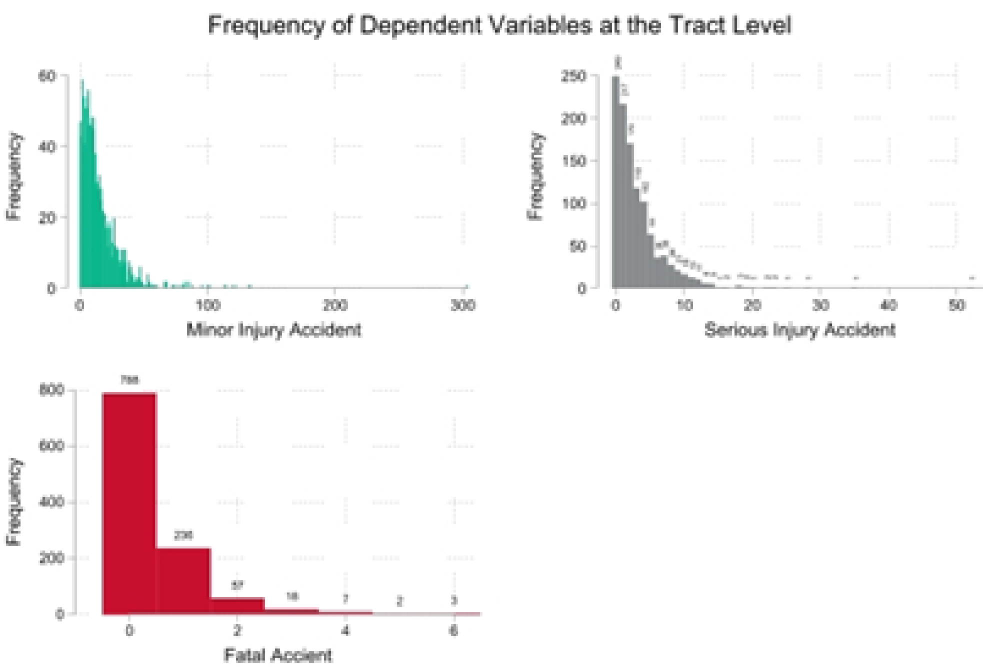

Table 7: Intersection Regression Results

VARIABLES	Crash Serious Injury Count	Crash Death Count	Crash Total Count
Average Annual Daily Traffic	2.44×10^{-6}	$1.33 \times 10^{-5}*$	-2.05×10^{-7}
	(2.94×10^{-6})	(6.91×10^{-6})	(6.91×10^{-7})
% of Trucks in AADT	0.0225**	0.0484**	0.00866***
	(0.0114)	(0.0231)	(0.00269)
Width of Lane (ft)	0.0111	−0.00611	−0.00423
	(0.0114)	(0.0321)	(0.00266)
speed limit	0.0293***	0.0414***	0.0110***
	(0.00554)	(0.0135)	(0.00130)
number of entering roads = 2, Three Entering Roads - Y	−0.213	−0.342	−0.0249
	(0.225)	(0.572)	(0.0481)
number of entering roads = 3, Four Entering Roads	0.121*	0.0248	0.142***
	(0.0630)	(0.152)	(0.0144)
number of entering roads = 4, 5 or More Entering Roads	0.414*	0.0283	0.108**
	(0.218)	(0.624)	(0.0522)
number of entering roads = 5, Other	−0.413	−17.52	−0.225**
	(0.547)	(7,248)	(0.109)
Light- Daytime	0.857*	0.587	0.148**
	(0.440)	(1.035)	(0.0715)
Light-Dusk	1.235**	2.179**	0.000814
	(0.508)	(1.109)	(0.0976)
Light- Dark, Lighted	1.343***	1.257	0.121*
	(0.441)	(1.039)	(0.0724)
Light- Dark, Unlighted	1.423***	1.240	0.0526
	(0.454)	(1.066)	(0.0787)
Light Condition, Dark, Unknown Lighting	0.724	0.913	-0.108
	(0.556)	(1.278)	(0.103)
First Harmful Event, Railroad	0.0802	-21.93	0.491***
	(0.655)	(127,673)	(0.117)
First Harmful Event, Pedestrian	2.093***	2.872***	0.584***
	(0.268)	(0.412)	(0.0894)
First Harmful Event, Bicycle	1.610***	1.904***	0.575***
	(0.231)	(0.445)	(0.0696)
First Harmful Event, Parked Car	-0.991	-22.59	-1.799***
	(1.056)	(139,933)	(0.329)
First Harmful Event, Other	1.220***	1.988***	0.0172
	(0.467)	(0.750)	(0.153)
Signal Present	0.0863	0.0378	0.137***
	(0.0601)	(0.150)	(0.0137)
Rush hour	-0.172***	-0.178	-0.0901***
	(0.0628)	(0.158)	(0.0137)
SVI	0.259**	0.0707	0.275***
	(0.116)	(0.281)	(0.0270)
car truck van	-0.00739	-0.0405	-0.00586*
	(0.0143)	(0.0371)	(0.00303)
public transport	-0.00265	-0.0432	0.0182***
	(0.0196)	(0.0543)	(0.00415)
Bicycle	-0.0997*	-0.132	-0.0346***
	(0.0574)	(0.163)	(0.0104)
Walked	-0.0128	-0.0736	-0.00492
	(0.0183)	(0.0525)	(0.00386)
min travel less 15	-0.00888	-0.0209	-0.00298
	(0.0152)	(0.0396)	(0.00322)
min travel 15to30	-0.00734	0.0235	0.00535*
	(0.0146)	(0.0380)	(0.00309)
min travel 30to45	-0.0123	0.0347	0.01000***
	(0.0152)	(0.0393)	(0.00324)
min travel more45	0.00949	0.000581	-0.0110***
	(0.0157)	(0.0402)	(0.00342)
EED	-0.563**	-0.0511	-0.0280
	(0.221)	(0.493)	(0.0390)
Constant	-5.659***	-7.234***	-1.266***
	(0.540)	(1.299)	(0.102)
Observations	76,564	76,564	76,564

Standard errors in parentheses
*** p¡0.001, ** p¡0.01, * p¡0.05

Table 8: Tract Regression Results

VARIABLES	Crash Severity Minor	Crash Severity Serious	Crash Severity Fatal
Average Annual Daily Traffic	3.75e-06***	2.47e-06**	5.82e-06***
	(8.87e-07)	(1.18e-06)	(2.17e-06)
Truck Annual Daily Traffic	0.0239*	0.0375**	0.0487
	(0.0132)	(0.0185)	(0.0357)
Lane Width	0.0202	0.0247	-0.0205
	(0.0131)	(0.0180)	(0.0416)
Rush Hour	0.0144***	0.0150***	0.0141***
	(0.000719)	(0.000925)	(0.00165)
Signal Present	0.000363	-0.000786	-0.00175**
	(0.000429)	(0.000501)	(0.000893)
Railroad Flag	-0.0382***	-0.0678***	-0.139***
	(0.00679)	(0.0127)	(0.0249)

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Table 8 – continued from previous page

VARIABLES	Crash Severity Minor	Crash Severity Serious	Crash Severity Fatal
SVI	0.205***	0.423***	0.567***
	(0.0708)	(0.102)	(0.218)
car truck van	0.00138	0.000328	-0.0389
	(0.00879)	(0.0138)	(0.0258)
public transport	0.00868	-0.00317	-0.108**
	(0.0128)	(0.0198)	(0.0430)
bicycle	-0.0109	0.00225	-0.0784
	(0.0265)	(0.0428)	(0.110)
walked	0.0221	-0.00746	-0.0321
	(0.0165)	(0.0240)	(0.0500)
min travel less15	-0.0158*	-0.0137	0.000215
	(0.00940)	(0.0145)	(0.0282)
min travel 15to30	-0.00783	-0.0150	0.0317
	(0.00920)	(0.0144)	(0.0270)
mint ravel 30to45	-0.00731	-0.0134	0.0417
	(0.00934)	(0.0143)	(0.0275)
min travel more45	-0.0136	-0.00206	0.0326
	(0.00946)	(0.0146)	(0.0282)
EED	0.00398	-0.0879	-0.172
	(0.121)	(0.169)	(0.371)
Constant	1.559***	-0.0134	-1.598***
	(0.189)	(0.268)	(0.589)
Observations	1,101	1,101	1,101

Standard errors in parentheses
*** p¡0.001, ** p¡0.01, * p¡0.05