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16. Abstract

Today, states have enacted laws to ensure that teen drivers are more skilled and drive safely. The result is fewer accidents. However, in previous research, when teen crashes were mapped, certain streets and areas appeared to have more accidents than other areas. The goal of this research is to investigate the “hot spot” locations where teens have accidents and to determine important factors contributing to the concentration of accidents. This research will benefit planners and engineers and help them determine if additional changes are needed at locations with high teen crashes to make these areas safer.

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A Hot Spot Analysis of Teenage Crashes: An Assessment of Crashes in Houston, Texas

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Research Report SWUTC/14/161341-1

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ABSTRACT

Today, states have enacted laws to ensure that teen drivers are more skilled and drive safely. The result is fewer accidents. However, in previous research, when teen crashes were mapped, certain streets and areas appeared to have more accidents than other areas. The goal of this research is to investigate the “hot spot” locations where teens have accidents and to determine important factors contributing to the concentration of accidents. This research will benefit planners and engineers and help them determine if additional changes are needed at locations with high teen crashes to make these areas safer.

EXECUTIVE SUMMARY

When a city or area reports numerous accidents all over the city, it becomes difficult to determine if there is any significance or pattern to the accidents. Using the Getis-Ord Gi, this study was able to determine where clusters of accidents occurred. These clusters (hot spots) indicated that these locations are critical areas where additional measures should be taken to curtail the number of accidents. While studying the City of Houston's teenage driver accidents, the following findings emerged:

- Teenage driver accidents decreased by 21% from 2006 to 2009.
- Hot spots (clusters of accidents) were found in Houston's CBD (central) area and West along Westheimer Road, and major intersections, i.e. IH 45, U.S. 59, US 290, and Loop 610.
- In 2006, hot spots proved to be popular locations for young adults, e.g. the Galleria shopping district, the CBD's entertainment district, and local clubs, bars and special events centers.
- In several locations, hot spots noted in 2006 reduced dramatically and turned into cold spots in 2009.
- Programs like the City of Houston's Red Light Camera program (along intersections at major freeways), traffic signalization in the CBD, access management improvements along Westheimer Road, and improved traffic maintenance contributed to the reduction in teenage driver accidents thereby creating more cold spots in previously hot accident locations.

While graduated driving programs have decreased teen driver accidents other factors may also benefit this cohort. In Houston, Texas it appears that measures that calm traffic and prevent crashes for other cohorts also provided an added benefit to teen drivers.

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1 INTRODUCTION

Motor vehicle crashes are the leading cause of death among teenagers. In 2011, persons 16 to 24 years old accounted for 21 percent of fatalities (NHTSA, 2011). For the past two decades, states imposed stricter regulations to decrease teenage motor vehicle crashes. Beginning in the 1990s, states implemented programs and initiatives to mitigate teen driver accidents. The Graduated Driver Licensing (GDL) program, which has a variation of the program in all 50 states, was the first to curb teen driver crash rates. The program is designed for novice drivers to obtain more driving experience, prior to obtaining complete driving privileges. GDL programs regulate driving among adolescents younger than 18 years old. There are three phases: (1) learning phase, supervised driving under any condition for 3-12 months, (2) intermediate stage, limits unsupervised driving in high risk situations such as daylight or additional adolescent drivers, (3) full driving privilege, a standard driver's license with no conditions.

Research shows the GDL are associated with crash reductions ranging from 20 to 40 percent (Williams, 2011). Since the inception of the GDL program, states implemented additional programs to curb teen driver crash rates. There are six primary recommendations (GHSA, 2013). First, strengthening GDL laws to ensure states have essential elements that address crash risk and skill building. Second, ensure understanding and enforcement of GDL laws by law enforcement officials. Third, engage parents in understanding, supporting and enforcing GDL laws. Fourth, strengthening driver education and training. Fifth, engaging teens in understanding and addressing driving risks. Sixth, garnering consistent media coverage of teen driving.

After eight years of decline, fatalities among teen drivers increased in 23 states (GHSA, 2013). The largest increase was found in motor vehicle crashes operated by 16- and 17-year olds (Appendix A). Among the 23 states, sixth-listed Texas posted a 4% increase in accidents by teen drivers, and came in first in the number of deaths. One major factor in teen accidents is seat belt use. Teen drivers are less likely to utilize their seat belts, resulting in more serious injuries and a higher percentage in deaths. To reverse this situation, the Texas Department of Transportation launched the statewide "Teen Click It or Ticket" campaign. The intiative strives to promote safe driving and seatbelt use to high school and college students (TXDOT, 2013).

This research study builds upon a preceding study of young drivers and senior drivers of three Texas cities: Houston, Pearland and Sugar Land. In that study, the reseach team noted potential clusters of accidents at several locations. This clustering proved worthy of further examination.

In this current study, motor vehicle crashes were examined for teen drivers age 15 to 24 years old driver crashes in Houston, Texas. Crash data was analyzed for the years 2006 and 2009. A spatial or hot spot analysis was conducted using Geographic Information Systems (GIS), with the intent of identifying teen driver crash locations or hot spots in Houston, Texas.

2 LITERATURE REVIEW

Arguably, the post-World War II American love affair with the automobile was a result of Hollywood marketing. Movie after movie highlighted Detroit's newest and shiniest cars as co-leads. Within a short period of time, young men across the country come to relate their masculinity with the "muscle" of the combustion engine. In the twenty-first century the American love affair with the car has waned tremendously, but young men still see their coolness wrapped in the paint and steel of their first cars. Sadly, many of Hollywood's new movies highlight the performance of "souped-up" cars racing down abandoned city streets. However, in the real world, downtown city streets are seldom abandoned.

The National Highway Traffic Safety Administration (the NHTSA) credits the original *Fast and the Furious* (2001) for reigniting the street racing craze among teenagers. The NHTSA believes street racing to be a factor in 135 fatal crashes involving teenagers, nearly double that of 2000.[1] Extensive literature already exists discussing the numerous factors influencing automobile accidents involving teenaged drivers including street racing, distracted driving, and simple inexperience. As mentioned above, the literature shows that Graduated Licensing Programs appear to reduce teen/young adult crashes. Policies and other laws, like blood alcohol concentration (BAC) limits, also appear to reduce fatalities for this cohort (Dee, 2001).

Instead of focusing on the cause of the crash, this literature review focuses on spatial applications to analyze high accident locations or "hot spots". To analyze crashes, engineers and planners look at accident incidents by time of day, speed, weather conditions, location, etc. Locations, like intersections, with high accident incidents are called "black spots" (Montufar, 2002; Dumbaugh, et al., 2011). These black spots indicate problem areas for drivers that must be fixed to decrease the loss of life, injury, and damage to property.

There are multiple approaches to examine crash data through spatial analysis, with unique attributes within these methods. In order to better understand how these variables work together, transportation professionals began using Geographic Information Systems (GIS), which is a mapping and analytical tool.

For almost two decades, researchers have used Geographic Information Systems for Transportation (GIS –T). Simply stated, GIS-T applies spatial technology to analyze and understand transportation issues. Montufar (2002) used GIS-T to help analyze heavy truck collisions (HTCs) in Canada. Her study utilized maps, HTC data, and truck volumes. GIS allows for more meaningful and multi-level examination of crashes. Dumbaugh, et al. (2011) explained the usefulness of GIS when analyzing accident locations and urban form in San Antonio, Texas.

Another example of crash data research discusses how roadway configurations and vehicle designs impact the severity of crash injuries, by assessing the robustness and shortcomings of different "methodological alternatives and limitations for examining such data" (Savolainen, Mannering, Lord & Quddus, 2011, p. 3). The study looks at an array of statistical techniques that can be utilized: Binary approach, like injuries versus non-injuries; an ordered discrete outcome model that assesses a sequence of no injuries, to disabling, to fatal; and multinomial

[1] http://www.secureteen.com/preventing-accidents/teenagers-2-fast-2-furious-for-their-own-good/

discrete outcome models that have no ordering whatsoever in the analysis (Savolainen, Mannering, Lord & Quddus, 2011). Dumbaugh and Rae (2010) assess urban design influence on crashes in the urban environment, using a negative binomial regression approach. This type of methodology displays the change in percentage of a dependent variable that occurs with each unit of change of an independent variable (Dumbaugh & Rae, 2010). Interestingly, the authors discussed early urban planners attempts to mitigate car safety issues; designing cul-de-sacs and constructing commercial districts near arterials led to more crashes, while higher density and more traditional shopping areas seemed to have considerably fewer incidences (Dumbaugh and Rae, 2010).

The collective versus individual approach to crash data is discussed by Abdel-Aty and Pande (2007) comparing the strategy of assessing where a single crash might occur instead of multiple ones over a duration of time. The contrast between the two is the individual incidents having an "estimation of real time crash likelihood", while multiple events examine "estimation of crash frequency over a period of time" (Abdel-Aty and Pande, 2007). Another way to analyze crash data, the Kernel Density approach, utilized by Xie and Yan (2008), creates a density estimation of a particular feature on a map. For this particular study, a planar kernel density approach, which is composed within a 2-D environment, was compared to a network kernel density, situated on a 1-D line (Xie & Yan, 2008).

Songchitruska and Zeng (2010) define hot spots, in their incident management report, as "the spatial distribution of crashes which are then used to identify the locations with a tendency to exhibit an unusually higher degree of collision hazard" (p. 2). They note a slight difference between the two types of hot spot analysis: one that is based on location, such as crashes at street crossings or sections of roads; and the other approach, that examines the noteworthy collection of crashes at certain locations (Songchitruska & Zeng, 2010). The Getis-Ord method showcases the distinction between "locations of high and low spatial associations", concurrently finding the regularity of events, the affiliated values, and geographical correlation spatially (Songchitruksa & Zeng, 2010, p. 4).

Based on the literature above, the research team selected the Getis-Ord Gi, or hot spot analysis approach, for examining crash data of teenage drivers in Houston, Texas. The hope is that this research will help metropolitan planning organizations, city officials, and transportation planners better understand how to analyze, manage and control high accident locations.

3 DESIGN OF STUDY

This research employs a case study approach to better understand the location of motor vehicle crashes among teen drivers. In a preceding study conducted by the Center for Transportation Training and Research, teen driver crashes were examined for the Houston, Sugar Land and Pearland. In this study, the unit of analysis was Houston, Texas. The goal of this study was to examine the spatial relationship of crashes throughout Houston. The hot spot analysis illustrates where clustering of accidents occurred, which could led to utilizing additional tools to understand novice driver accidents.

Hot Spot Analysis

To determine if Houston, Texas contained areas with high novice driver accidents, the hot spot analysis tool was applied. The Getis-Ord Gi statistical model considers the aggregation of crashes at points within Houston, Texas. ESRI Resources describes the hot spot analysis as the following:

> *A tool calculates the Getis-Ord Gi* statistic for each feature in a dataset. This test assesses whether the clusters of crashes are statistically significant. The resultant Z score tells you where features with either high or low values cluster spatially. This tool works by looking at each feature within the context of neighboring features. A feature with a high value is interesting, but may not be a statistically significant hot spot. To be a statistically significant hot spot, a feature will have a high value and be surrounded by other features with high values as well. The local sum for a feature and its neighbors is compared proportionally to the sum of all features; when the local sum is much different than the expected local sum, and that difference is too large to be the result of random chance, a statistically significant Z score results* (ESRI resources, n.d.).

The formula is shown below.

The Getis-Ord local statistic is given as:

$$G_i^* = \frac{\sum_{j=1}^{n} w_{i,j} x_j - \bar{X} \sum_{j=1}^{n} w_{i,j}}{S \sqrt{\frac{\left[n \sum_{j=1}^{n} w_{i,j}^2 - \left(\sum_{j=1}^{n} w_{i,j} \right)^2 \right]}{n-1}}} \quad (1)$$

where x_j is the attribute value for feature j, $w_{i,j}$ is the spatial weight between feature i and j, n is equal to the total number of features and:

$$\bar{X} = \frac{\sum_{j=1}^{n} x_j}{n} \quad (2)$$

$$S = \sqrt{\frac{\sum_{j=1}^{n} x_j^2}{n} - \left(\bar{X}\right)^2} \quad (3)$$

The G_i^* statistic is a z-score so no further calculations are required.

Source: ESRI resources, n.d.

Figure 1: Getis Ord

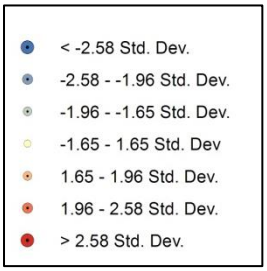
Analysis

Motor vehicle crash data were assembled from the Texas Department of Transportation, and pertinent attributes were selected. The Getis Ord Gi star statistical analysis tool was utilized in ArcGIS, which was to scan for clusters of high value and low value Z-scores. It showcases that a cluster of points has more in common with adjacent points than those further away. A GiZscore, which is a Z-score from Getis Ord Gi Star test, was used in this analysis. An appropriate conceptualization of spatial relationship was also chosen, the Zone of Indifference, using a critical distance to decide the most applicable neighbors to incorporate. The critical distance chosen was 1,000 meters

The Getis Ord G star statistical approach provided the GiZscore. When there is a high positive value for a GiZscore, it means a hotspot is encompassed in an area of a statistically significant cluster. Similarly, with high negative value for a GiZscore there is a cold spot, within proximity of a statistically significant cluster. Another method to exhibit statistical significance is with the P-value, determining probability, and showing if a hot spot, cold spot, or shown spatial pattern is random. So both hot spots and cold spots with P-values under .05 had a less than 5% chance of being random, representing another form of statistical significance.

ArcGIS was used to shape and visually exhibit the age groups and crashes. Maps showing crashes by the 15-24 age cohort were composed. Table 1 shows the range of GiZscores and corresponding colors for this study. The color red represents the highest GiZscores or hot spots. Blue represents points with the lowest GiZscores or cold spots.

Table 1: GiZscores



4 RESULTS

Overall, teen drivers, ages 15-24, registered 10,718 crashes in 2006. That number decreased to 8,464 in 2009. (See Figures 2 and 3.) This represents a decrease of roughly 21%. While this decrease remains important, the location of the accidents and the identification of clusters prove interesting as well.

Mapping Crashes

Figures 4 shows that in 2006, most crashes occurred near the center of Houston, where I.H. 45, I.H. 10, and U.S. 59 cross. Furthermore, areas around I.H. 610 and U.S. 59, the Galleria area, show a large number of hot spots. Hotspots remain robust at the interchanges of I.H. 610 and U.S. 290, as well I.H. 610 and I.H. 45. Otherwise, the hot spots are scattered near various major primary roads. Hot spots represented 4.3% of crashes. The cold spots, which represent 3.5% of crashes that year, are scattered throughout the city.

In 2009, the highest concentration of hotspots is seen around I.H. 45 in the center of the city. (See Figure 5.) Otherwise, hot spots are shown across the city. Hot spots represent 3.3% of crashes in this year. The cold spots decreased slightly, representing 3.4% of all crashes, distributed widely across the city.

A closer examination of the crashes reveals that the hot and cold spots are seen in several quadrants of the city, e.g. west and central. Figure 6 - 2006 Central highlights hot spots. Heavy clustering in the Central Business District, just south of I-10, occurs near the Harris County Courthouse, performance centers (Jones Hall, Wortham Theater), the central U.S. Post Office, and the University of Houston-Downtown. Hot spots are also seen along Louisiana, Main, and Fannin Streets, where Shell Oil Company, federal offices, and City Hall are located. Clusters of accidents appear along U.S. 59 and I-45 near special events areas, Toyota Center (basketball center), the George R. Brown Convention Center, Minute Maid Park (baseball stadium), and Discovery Green Park. As seen in most cities, Houston's CBD consists of numerous one way streets which could prove challenging for novice drivers; this could account for part of the rationale for the hot spots.

Moving just outside of the CBD into the Midtown District, clusters of accidents are found along Brazos, Smith, Fannin, and Main Streets. Over the past decade, this area benefited from substantial redevelopment efforts that created a more pedestrian friendly environment. This area contains bars, shopping, dining, and residential living, attracting singles, professionals, and young adults. Clusters are also visible along Elgin Street. This area contains the Houston Community College Culinary School and administrative building, a large fabric retailer, and businesses.

Further south of the CBD, the intersection of Westheimer Road and Montrose Boulevard, had a number of dense crash locations. At the intersection of Kirby Drive and U.S. 59, numerous clusters of incidents are seen. All these locations have robust pockets of entertainment, shopping and restaurant establishments used by this cohort.

Finally, along U.S. 59, large clusters appear around Wheeler at San Jacinto and Main Streets. This location has a large grocery store and retailer. Additional problems are noted at Richmond Avenue and Spur 527, which leads into the CBD. The intersections of Kirby Drive at U.S. 59 and Kirby Drive at Richmond Avenue also show substantial accidents, as this is one of the main thoroughfares into the Greenway business district.

In 2009, Figure 7 – 2009 Central shows marked improvements from 2006. As noted in the citywide map, the 2009 central map recorded less crashes and highlighted tremendously fewer hot spots. Traffic accidents and issues in the CBD and along Westheimer Road and Richmond Avenue were resolved via traffic and signalization improvements. Nonetheless, problem areas are still seen in the Midtown District, south of I.H. 45, which substantially increased the number of hot spots. This area continues to draw and cater to young professionals with its retail, restaurants, and lounges. Finally, the area straddling Dowling and I.H. 45 registered a sharp increase in hotspots.

Travelling along major freeways proved troublesome for young drives as U. S. 59 and I-610 show numerous hot spots primarily concentrated at intersections. This interchange proves cumbersome for a novice, because drivers must navigate merges from the both sides of the vehicle. Figure 8 – 2006 West shows hot spots along Westheimer, especially near the intersection with I-610 and at Chimney Rock Drive. This is mostly in the Galleria area, where diverse concentration of employment, shopping, dining, and entertainment attracts this cohort and others to the area. Less intense clusters (1.96 -2.58 standard. deviation and 1.65 – 1.96 standard deviation) are seen along Richmond Avenue and U.S. 59 at Chimney Rock Road, Fountain View Drive, and Hillcroft Avenue. These areas contain more residential uses, shopping, dining, retail, and commercial uses.

Three years later, the data show a different story. Figure 9 – 2009 West displays a snapshot of Houston showing there are fewer crashes than in 2006. In addition, with the exception of Hillcroft Street at Westpark, no concentration of hotspots is noted. Again traffic calming, signalization, and general traffic management improved these areas dramatically. In fact most of these intersections moved to a standard deviation between -1.65 to 1.65.

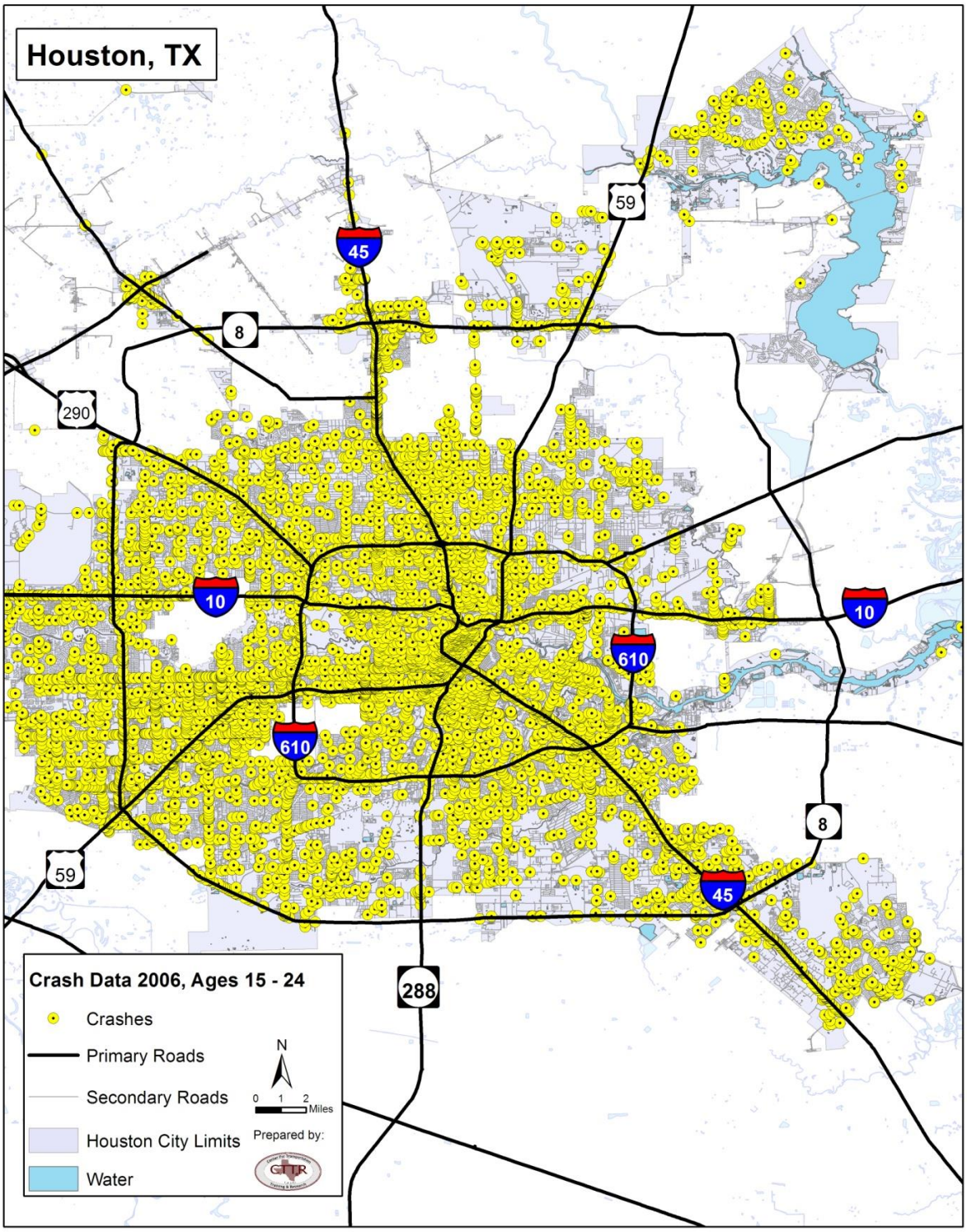


Figure 2: 2006 Crashes for Drivers ages 15-24

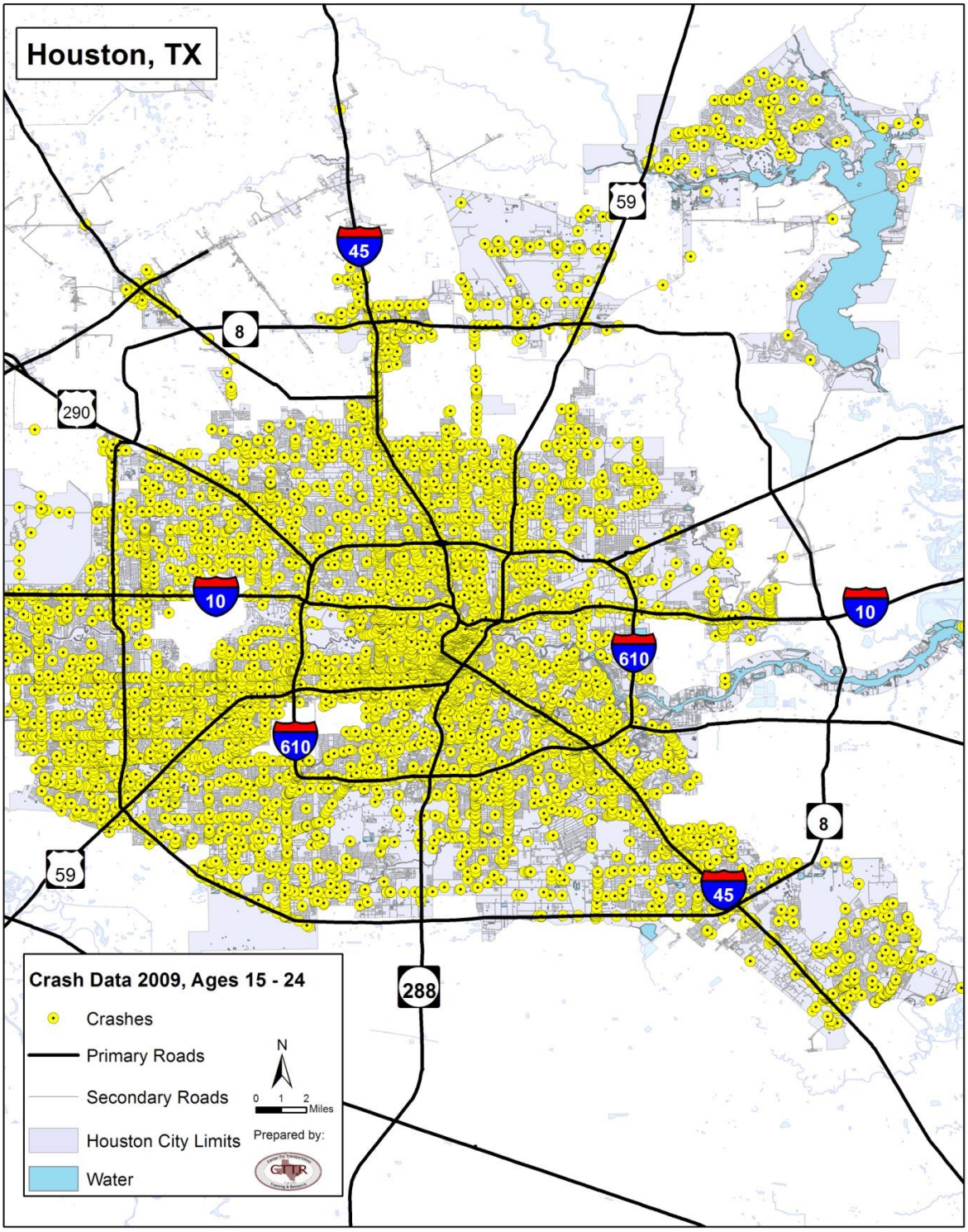


Figure 3: 2009 Crashes for Drivers ages 15-24

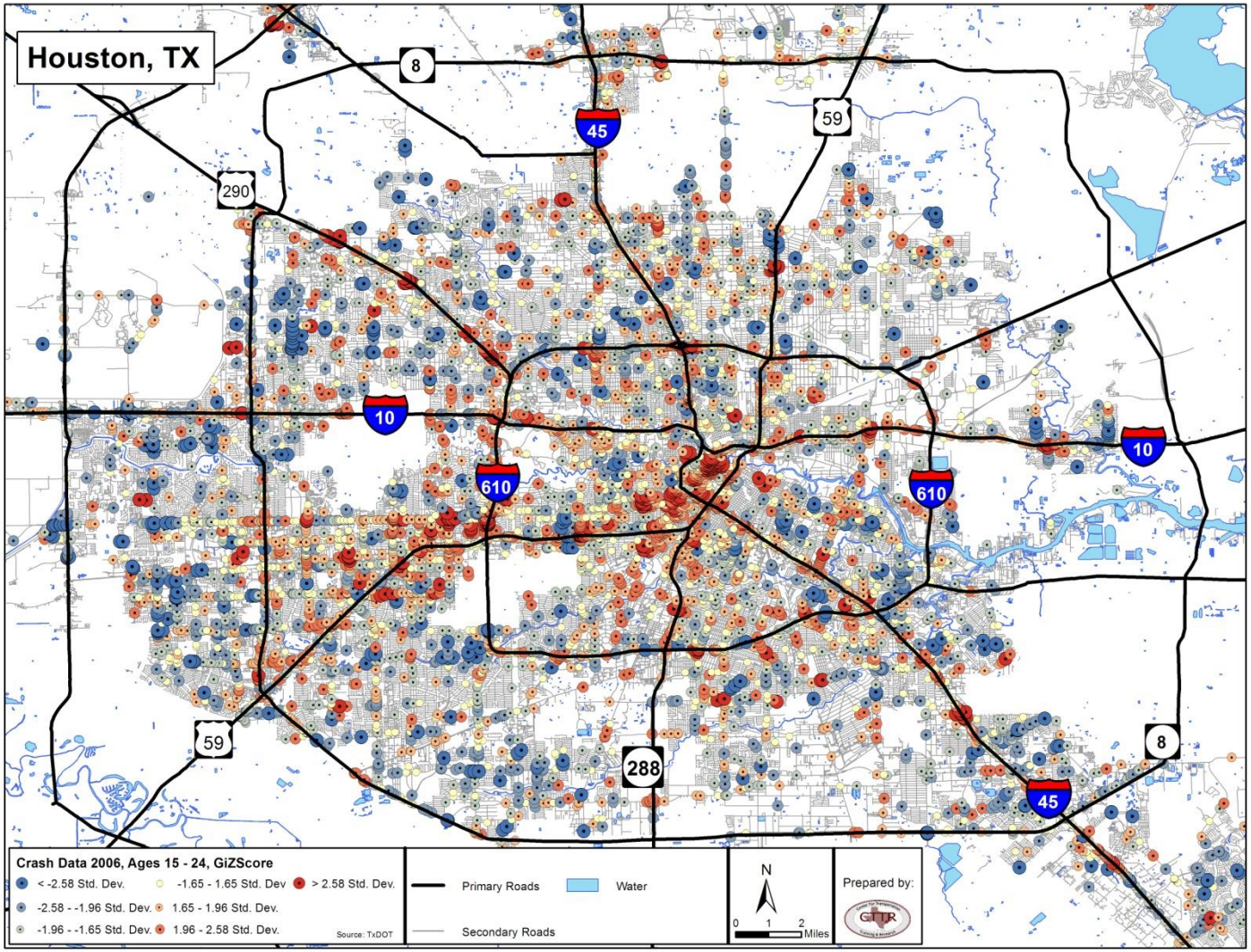


Figure 4: 2006 GiZScore Houston, Texas

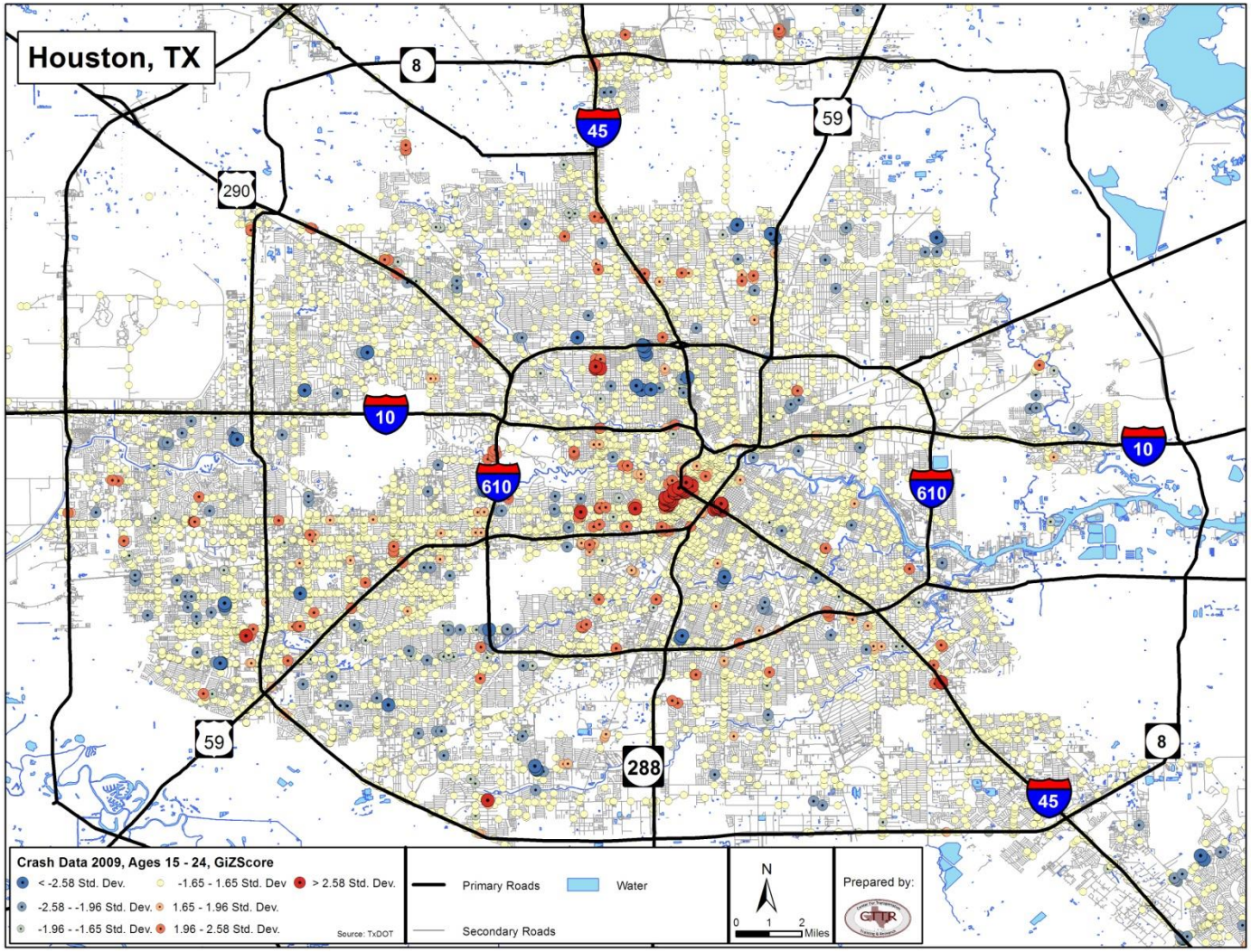


Figure 5: 2009 GiZScore Houston, Texas

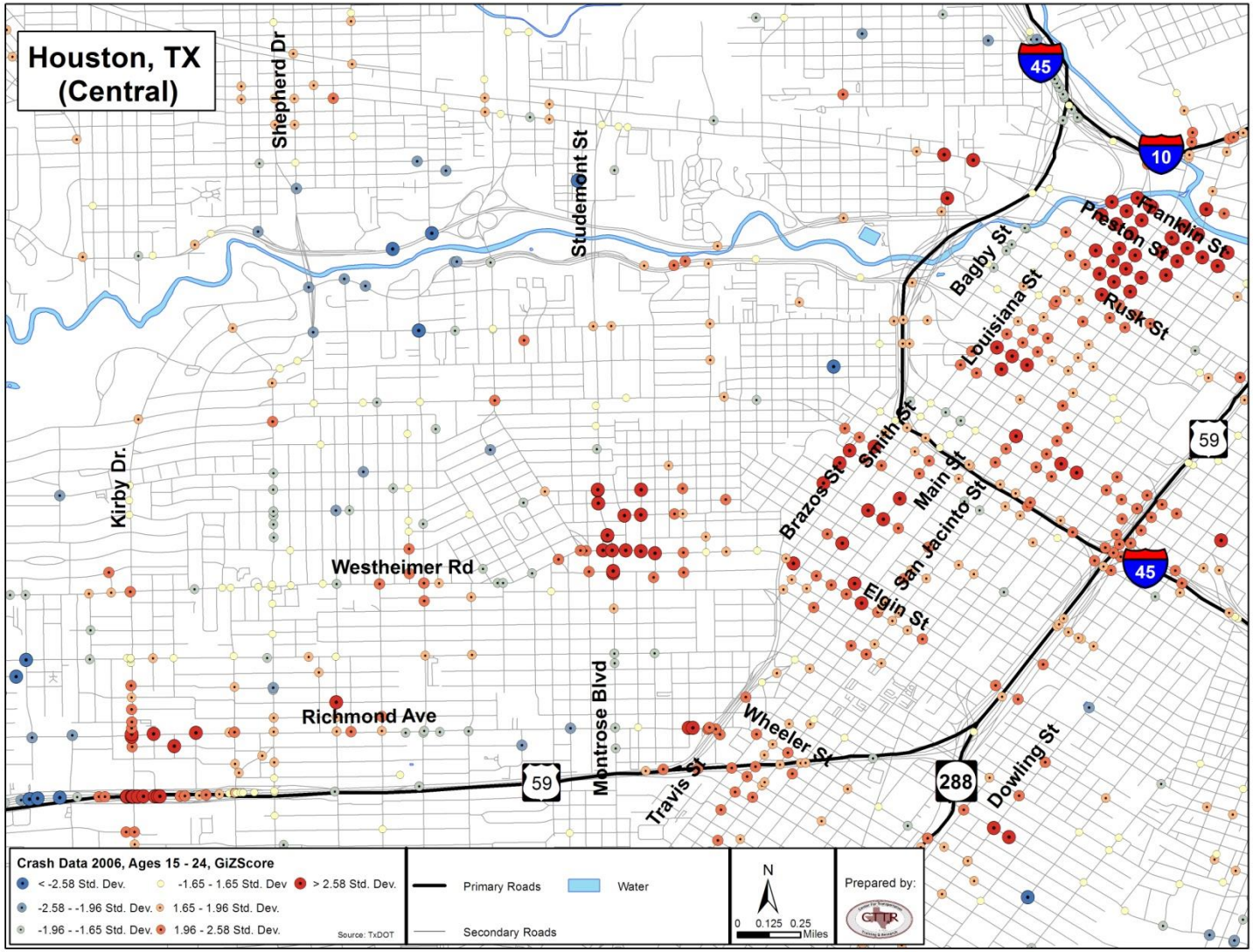


Figure 6: 2006 GiZScore Central Houston, Texas

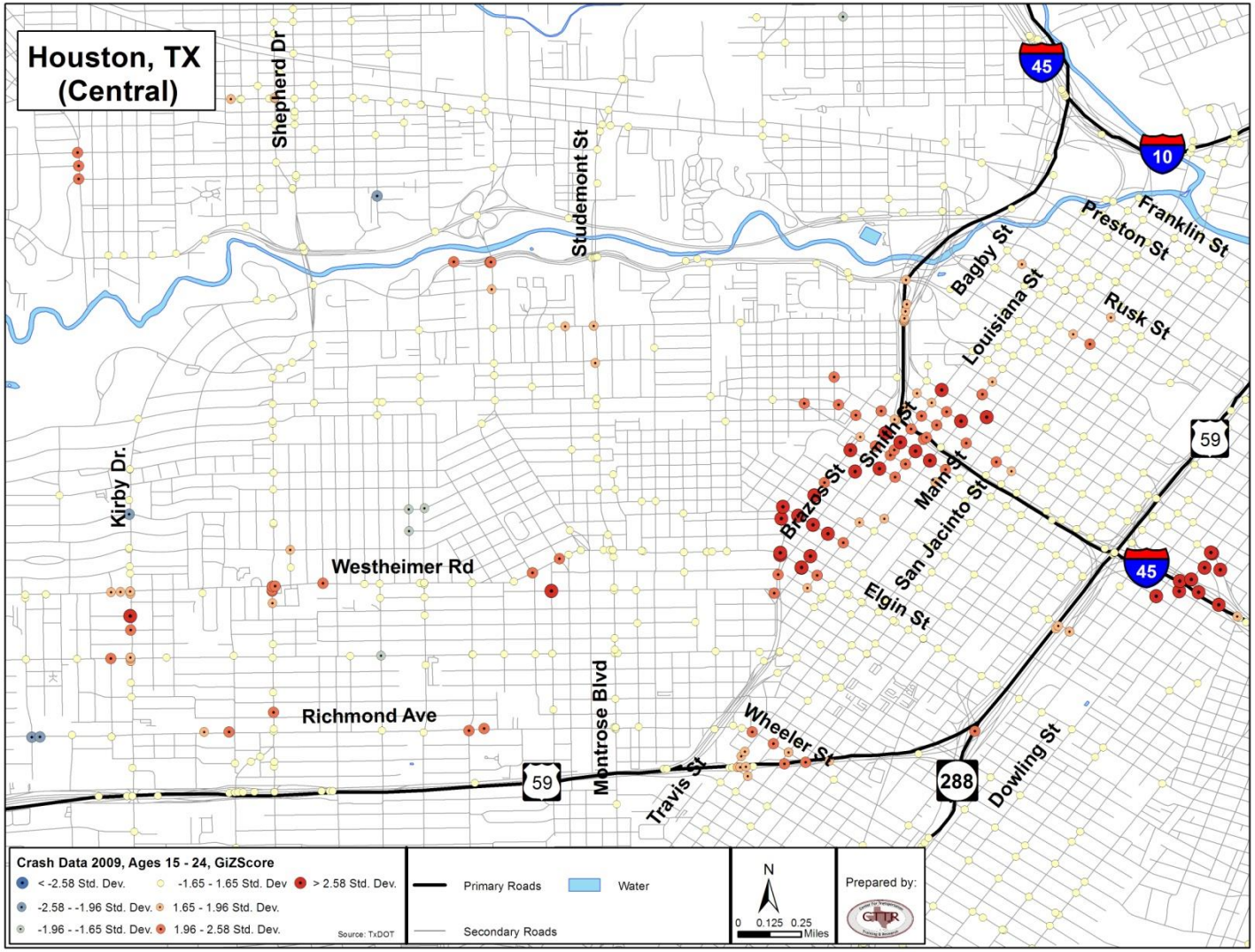


Figure 7: 2009 GiZScore Central Houston, Texas

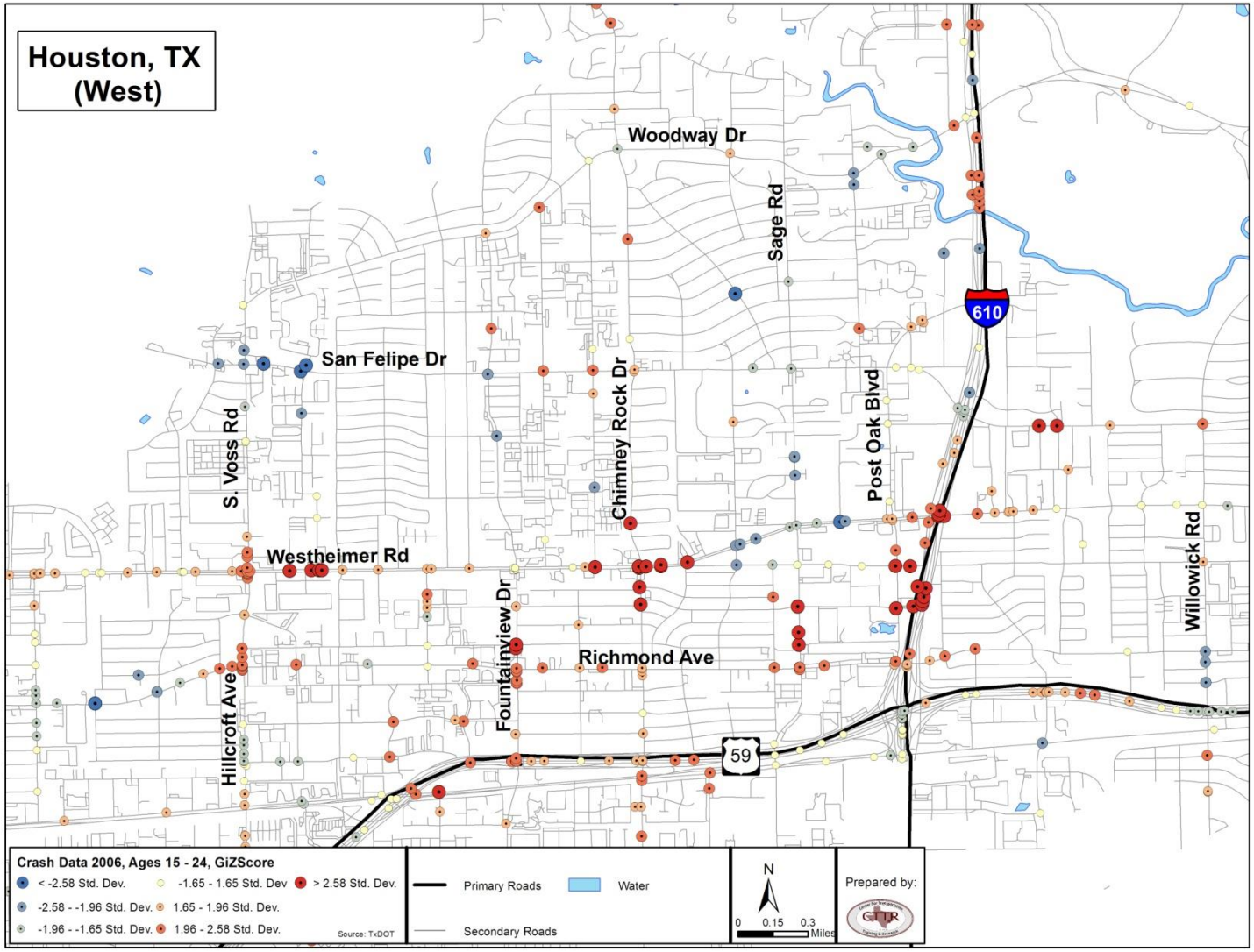


Figure 8: 2006 GiZScore West Houston, Texas

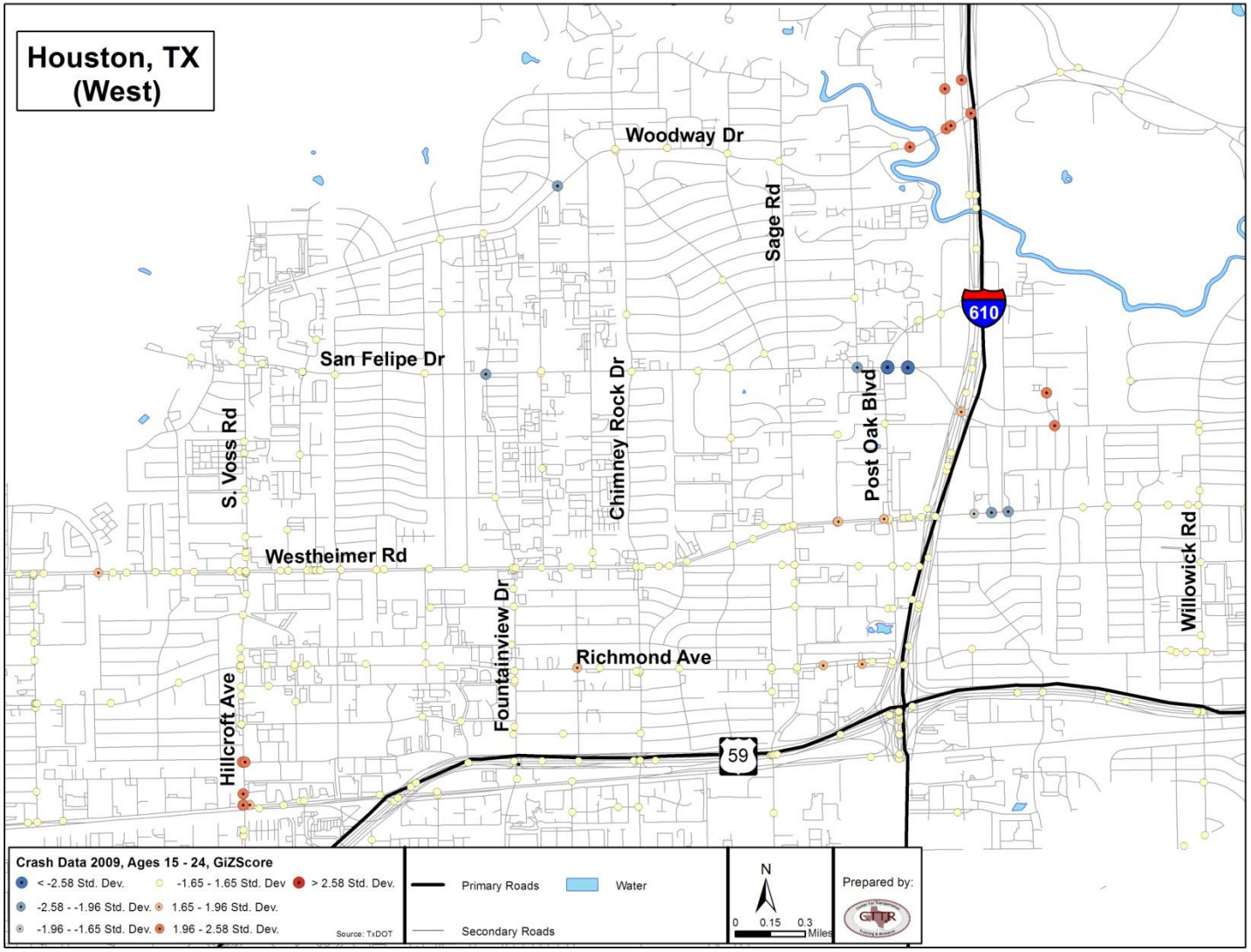


Figure 9: 2009 GiZScore West Houston, Texas

Other contributing factors to the results

With all the decreases in crash rates, especially when looking at various locations, the research team became curious about the reasons behind the changes. After reading and interviewing professional planners, several key factors emerged. The following issues played a significant role in accidents decreasing for teen drivers:

- Prior to 2006, the City of Houston, had not established a traffic signal preventive maintenance program. Once the program was implemented traffic signals malfunctions became fewer, thus resulting in fewer opportunities for drivers to misinterpret whether or not it was their turn to move.
- Starting in 2006 through 2009, traffic signal timing upgrades occurred at numerous intersections. City of Houston staff noticed that after these upgrades were implemented, the intersections operated more safely.
- In 2007, Traffic signals were upgraded to LEDs with 12" heads. City officials believe this led to safer intersections.
- The economy and rising gas prices of 2008 impacted travel behavior causing more people to select transit over driving alone.
- In 2007, the City of Houston developed a new traffic signal timing plan for the CBD. This new plan used a progressive green signal instead of continuous green lights. This eliminated cars making stops at each block, which improved traffic flow. This measure also controlled speeds and improved safety. City officials noted a drop in crashes in the CBD.
- The City of Houston red light traffic camera (photo enforcement) program was implemented after 2006. This program placed seventy (70) cameras along critical intersections. These cameras recorded vehicles that ran red lights.
- By 2009, the Texas Department of Transportation (TxDOT) completed access management improvements along Westheimer (FM 1093). Some of the improvements included right turn bays, driveway consolidations, median closures, median channelization, left turn bay extensions, and signalization improvements. These changes meant fewer crashes and improved flow of traffic along the street.

5 CONCLUSION

Using data from Texas Department of Transportation crash data in 2006 and 2009, this study examined the location of crashed caused by young drivers ages 15-24. Hot spots and cold spots were noted. The following provides the highlights of the study.

- Teenage driver accidents decreased by 21% from 2006 to 2009.
- Hot spots (clusters of accidents) were found in Houston's CBD (central) area and West along Westheimer Road, and major intersections, i.e. IH 45, U.S. 59, US 290, and Loop 610.
- In 2006, hot spots proved to be popular locations for young adults, e.g. the Galleria shopping district, the CBD's entertainment district, and local clubs, bars and special events centers.
- In several locations, hot spots noted in 2006 reduced dramatically and turned into cold spots in 2009.
- Programs like the City of Houston's Red Light Camera program (along intersections at major freeways), traffic signalization in the CBD, access management improvements along Westheimer Road, and improved traffic maintenance contributed to the reduction in teenage driver accidents thereby creating more cold spots in previously hot accident locations.

While graduated driving programs have decreased teen driver accidents other factors may also benefit this cohort. In Houston, Texas it appears that measures that calm traffic and prevent crashes for other cohorts also provided an added benefit to teen drivers.

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