Effectiveness of Transportation Safety Improvement Projects in Austin, Texas

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ABSTRACT

Following a record number of fatalities on Austin roads in 2015, Austin Transportation Department established Transportation Safety Improvement Program to address high priority safety issues with safety engineering countermeasures, to reduce fatal and serious crashes on roads. Transportation Safety Improvement Program planned, designed, and constructed safety engineering improvements at five high priority intersections with fund allocated by the Austin City Council. The safety engineering improvements implemented at the intersections to reduce serious crashes included geometric changes such as revision of lane configuration and alignment removing off-sets, construction of right-turn island / pedestrian refuge, 'smart' right-turns, and raised median to provide access management at the intersection approaches as well as additional traffic signals, pedestrian signals, and warning flashers. After completion of these safety improvements, Austin Transportation Department conducted before-and-after studies using Empirical Bayes Method accounting for the annual fluctuation in crashes (regression to mean bias). The results showed significant reduction in crashes at the treated intersections. Preliminary results revealed an annual overall crash reduction of 21 to 56 percent at these intersections. With respect to reduction in severe crashes, the results came out even better; the safety engineering countermeasures were found to effectively reduce severity risks at the intersections by 40 to 100 percent. These robust results dictate the great success of the safety engineering techniques applied in planning, design and construction at the high priority intersections.

BACKGROUND

Traffic crashes have become an epidemic and lethal problem in United States. On an average over six million crashes are reported, and about 35 thousand people lose their lives in fatal crashes on US Roads every year. Additionally, 2.4 million people are injured in severe crashes (1). In the recent years, this crisis has gotten worse with an increase in fatalities from 32,479 in 2011 to 37,461 in 2016 with a significant increasing trend. The situation is even worse in Texas. About 10% of the total fatalities in US are reported in Texas in 2017 (2). Out of all the crash locations in the roadway system, intersections are recognized as the most hazardous locations on roads since conflict possibilities are high at intersections. This often results in a high frequency of fatal and severe crashes at intersections. Although intersections constitute only a small proportion of the entire roadway system, a significantly high proportion of crashes are reported at intersections. More than 50 percent of the combined fatal and injury crashes occur at or near intersections (3). Many of these fatal and severe crashes reported at intersections are preventable if the contributing factors can be identified, and safety engineering countermeasures are implemented to combat the identified factors.

Following the trends in US and Texas, Austin experienced a spike in traffic fatalities in 2015. In order to combat the fatal and serious crashes, Austin Transportation Department established Transportation Safety Improvement Program to address the safety issues at high priority intersections. As part of this initiative, a series of intersections were identified as high priority intersections based on different safety performance parameters such as crash frequency, crash rates, severity level of crashes i.e. frequency and rate of serious crashes, and patterns of crashes that can be addressed with engineering solution. This paper assesses the effectiveness of the safety engineering techniques applied and highlights the success of the safety engineering countermeasures implemented at high priority intersections.

LITERAURE REVIEW AND METHODOLOGY

As intersections are considered as the most hazardous location in the roadway system, researchers and transportation engineers conducted significant research to identify the geometric and operational factors that increase the likelihood of fatal and serious crashes at intersections. Chin & Quddus 2003 (4); Yan et al. 2005 (5); Barua & Tay 2007; Haung et al. 2008; Das et al. 2009; Das & Abdel-Aty 2010; Barua et al. 2010; and Das & Abdel-Aty 2011 conducted rigorous research to identify the engineering factors that affect the likelihood of severe crashes at intersections. Wong & Li (2007) used Poison Regression Model and Negative Binomial Model to explore the relationship betweennumber and severity of crashes and road and environmental characteristics at signalizedintersections. Wang & Abdel-Aty (2008) used generalized estimating equations (GEE) with the negative binomial as the link function to explore the effect of human, vehicle, road and environmental characteristics on number of crashes for different left-turn patterns at signalized intersections. Barua et al. 2010 applied logistic regression model and examined the factors that contribute to the fatality risk of intersection crashes and identified countermeasures that can reduce fatality risks at intersections. Of the significant factors, the major ones affecting the likelihood of fatality were found to be type of intersection, horizontal and vertical alignments of the roadway at the intersection, signalization at the intersection, type of crash, impairment of drivers, and age of drivers involved in crashes. Specifically, the fatality risk of intersection crashes was found to increase when crashes occur at offset intersections or at cross or T-intersections on horizontal curves. This result implies that removal of off-set by realignment of intersection approaches can significantly reduce fatality risks at intersections. The study also found that likelihood of fatality tends to increase if the intersection is on a sag curve or at a constant downhill grade. This implies that designing intersections at a sag curve or on steep grade should be avoided to reduce fatality and severity risks. Re-grading of intersection approaches to remove sag curve would significantly reduce fatality risks at intersections. The study also found that signalization of intersections where warranted reduce the likelihood of a fatal crash.

These specific finding on geometric and operational improvements were considered at the high priority intersections that were selected for safety improvements in Austin, Texas. Crash data from Austin Police Department was collected and plotted at the intersections for identifying the patterns of crashes that can be treated with safety engineering countermeasures. Based on the crash analysis and plotting, a series of engineering countermeasures were developed for consideration from the safety engineering research mentioned above. Traffic safety and operational analyses were performed for different countermeasure options and most effective safety engineering countermeasures were selected for implementation.

After going through engineering design, construction, and implementation of the safety improvements, crash data was collected for the after period. Before-and-after studies were completed comparing yearly crash frequency before and after the implementation of safety improvement projects. Effectiveness of the safety improvements was assessed applying the Empirical Bayes method contained in Highway Safety Manual (HSM, 2010) to account for the annual fluctuation in crashes (regression to mean bias).

SITE SELECTION

The sites for the implementation of safety improvements were selected based on several safety performance parameters e.g. crash frequency, crash rate, frequency of severe crashes, and rate of severe crashes. Discernable pattern and cluster of crashes were also considered while selecting the sites for safety improvements. Using all these safety performance parameters, five locations were selected for implementation of safety improvements:

- N. Lamar Boulevard / Parmer Lane;
- N Lamar Boulevard / Rundberg Lane;
- US 183 Service Road / Cameron Road;
- IH-35 Service Road / MLK Boulevard; and
- Slaughter Lane / Manchaca Road.

To date, safety improvements have been completed at the first four intersections, and construction at the fifth intersection (Slaughter Lane / Mancahca Road) is currently underway.

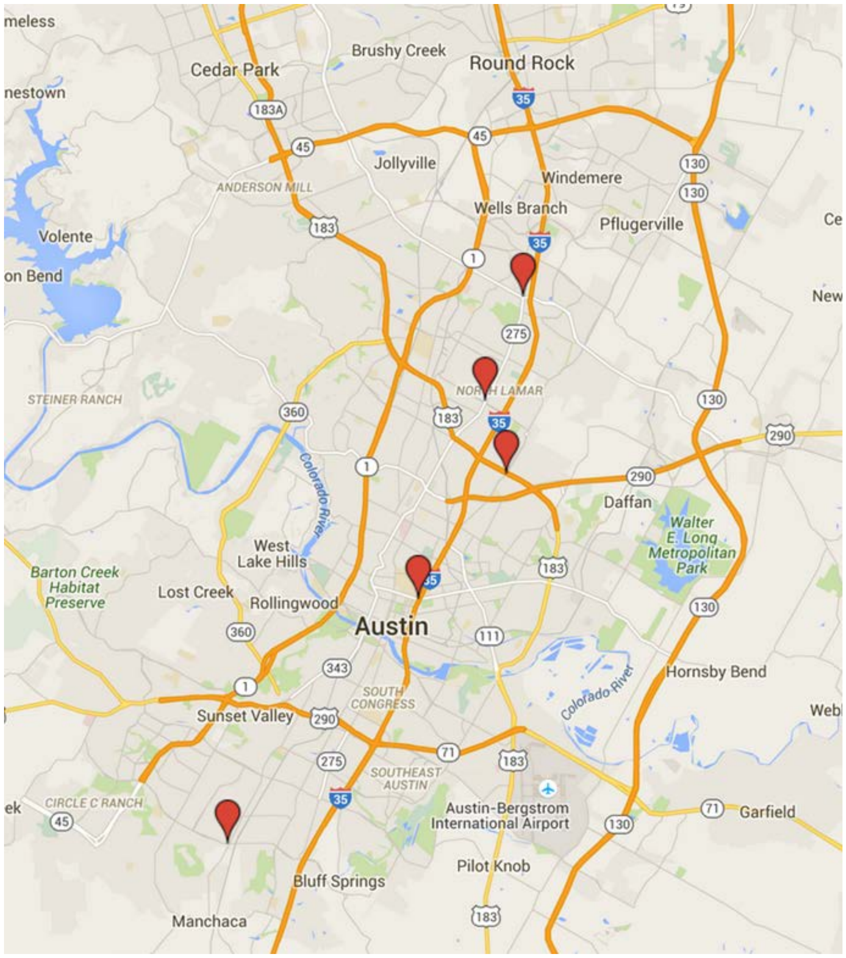

Figure 1: Location of Safety Improvement Projects in Austin, Texas

SAFETY IMPROVEMENTS AT NORTH LAMAR BOULEVARD / PARMER LANE

Both North Lamar Boulevard and Parmer Lane are major arterials located in north Austin. Parmer Lane is a six-lane divided arterial and runs east-west through the project location. N. Lamar Boulevard is a four-lane arterial and runs north-south through the project location. In the crash analysis, a significant cluster of crashes was identified at the northbound and southbound right-turns. In the analysis it was found that most of these crashes were attributed to the wide angle, high speed right turns at the intersection. After assessing many safety engineering countermeasure options, implementation of ‘smart’ right-turns was selected as the most effective and feasible option to combat the identified safety issue. This new right-turn design scheme, ‘smart’ right-turn decreases the angle of the channelized right turn to approximately 70°. A ‘smart’ right-turn widens the cone of vision of the driver towards the pedestrians as well as cross-traffic. Thus, smart right-turns allow for safer pedestrian crossing and also improve vehicle–vehicle interactions since the new approach angle affords drivers a better view of the traffic stream they are to merge with. Figure 2 below shows the right-turn configuration at N.

Lamar Boulevard / Parmer Lane in the ‘before’ condition. Figure 3 presents the right-turn configuration at the intersection after the construction of the ‘smart’ right-turn.

Figure 2: Project Location: N. Lamar Boulevard / Parmer Lane North in Austin, Texas

Figure 3: Smart Right-turn at N. Lamar Boulevard / Parmer Lane North in Austin, Texas

Effectiveness of Safety Improvements at North Lamar Boulevard / Parmer Lane

In order to assess the safety effectiveness of the improvements implemented at this intersection, before and after crash data were collected at the corresponding right-turns. The table (Table 1) below shows the comparison of crash statistics before and after the safety improvements are implemented.

Table 1: Before-and-After Crash Statistics at Right-turns at N. Lamar Boulevard / Parmer Lane

Before Period	**Severe Crashes**	**Total Crashes**
July 2016 - June 2017	2	7
July 2015 - June 2016	9	10
July 2014 - June 2015	7	12
July 2013 - June 2014	6	6
July 2012 - June 2013	2	4
July 2011 - June 2012	13	15
Annual Frequency	6.5	9
Construction of Safety Improvements	**Late June 2017**	
After Period	**Severe Crashes**	**Total Crashes**
After (July 2017 - March 2018)	2	3
Annual Frequency	2.7	4
Percent Reduction	**59%**	**56%**

The before-and-after data shows that the smart right-turns effectively reduced the number of right-turn crashes by 56% and severe (fatal and serious injury) right-turn crashes by 59%.

However, this is understood that these raw results of crash reductions are susceptible to regression to mean bias. In order to account for the regression to mean bias and calculate the true effectiveness of the safety improvements, Empirical Bayes (EB) method was applied. Empirical Bayes method uses existing Safety Performance Functions (SPFs) to predict average crash frequency before and after the implementation of safety improvements. EB method combines the observed crash frequency (before period) and the SPF predicted average crash frequency (before and after periods) to estimate the expected average crash frequency in the after period had the improvement not been implemented. The comparison of the observed crash frequency in the after period to the expected average crash frequency in the after period, provides the effect of the safety improvements implemented at the intersection.

Safety performance function for a signalized intersection was developed in Highway Safety Manual (12) and is given by:

$$N = Exp\ [-5.13 + 0.60 \times Ln\ (AADT_{maj}) + 0.20 \times Ln\ (AADT_{min})] \quad (1)$$

where N is the expected number of crashes per year, $AADT_{maj}$ is the average annual daily traffic on the major intersecting road, and $AADT_{min}$ is the average annual daily traffic on the minor intersecting road. The benefit of safety improvements (smart right-turns) can be assessed in terms of reduction in severe and total right-turn crashes. In order to focus on the right-turn crashes, (1) is modified to provide expected number of right-run crashes per year (N_{Rt}),

$$N_{Rt}=0.426 \text{ x Exp } [-5.13+0.60 \text{ x Ln } (AADT_{maj}) + 0.20 \text{ x Ln } (AADT_{min})] \quad (2)$$

Applying (2) to each year in the before period, the total predicted right turn crashes for the before period [July 2011 to June 2016] ($\sum_{Before\ Period}(N_{Predicted})$) was calculated to be 73.95 crashes.

The overdispersion parameter for a signalized intersection is given by

$$k= 0.11 \quad (3)$$

The weighted adjustment for the before period is given by

$$w = \frac{1}{1+k\ \sum_{Before\ Period}(N_{Predicted})} \quad (4)$$

The expected average right turn crash frequency for the before period is given by,

$$N_{expected,B} = w * N_{predicted,B} + (1-w) * N_{observed,B} \quad (5)$$

Using, equations (3), (4), and (5), the expected average right-turn crash frequency for the before period ($N_{expected,B}$) was calculated as 42.83 crashes.

The predicted average right-turn crash frequency for the after period($N_{Predicted,A}$) was calculated using equation (2) and was found to be 9.77 crashes.

The adjustment factor, r, to account for the differences between the before and after periods in duration and traffic volume at the study segment is given by,

$$r = \frac{\sum_{After\ Period}(N_{Predicted,A})}{\sum_{Before\ Period}(N_{Predicted,B})} \quad (6)$$

The expected average crash frequency for the after period is given by

$$N_{expected,A} = N_{expected,B} * r \quad (7)$$

Using equations (6) and (7), the expected average right-turn crash frequency in the after period (had the safety improvements not been implemented) was calculated. It was found that 5.66 crashes would have occurred at the right-turns in the after period, had the smart right-turns not been constructed at the intersection.

The overall reduction of right-turn crashes after the implementation of smart right-turns was calculated by

$$Safety\ Effectivenss = \left(1 - \frac{N_{observed,A}}{N_{expected,A}}\right) \times 100\% \quad (8)$$

Using equation (8), the overall reduction in right-turn crashes at the intersection of N. Lamar Boulevard / Parmer Lane after the implementation of smart right-turns was calculated to be 47%. This overall reduction in right-turn crashes reflects the effectiveness of smart right-turns in reducing total right-turn crashes.

The evaluation of the safety benefit of smart right-turns can also be assessed comparing of severe right-turn crashes before and after the implementation of the smart right turns. Following similar procedure and applying Empirical Bayes Method, the effective reduction of severe right-turn crashes at the intersection of N. Lamar Boulevard / Parmer Lane was found to be 40%. This reduction in severe right-turn crashes reflects the effectiveness of smart right-turns in reducing severity risks in right-turns at intersections.

Table 2: Effectiveness of Safety Improvements at N. Lamar Boulevard / Parmer Lane

Safety Effectiveness	Reduction in Severe Right-turn Crashes	Reduction in Total Crashes
Raw Annual Reduction	59%	56%
Effective Reduction Applying Empirical Bayes Method	40%	47%

SAFETY IMPROVEMENTS AT NORTH LAMAR BOULEVARD / RUNDBERG LANE

Both North Lamar Boulevard and Rundberg Lane are major arterials located in north Austin. North Lamar Boulevard and Rundberg Lane are four-lane divided arterials and run north-south and east-west respectively. In the crash analysis, patterns of crashes were identified at the driveways adjacent to this intersection. Most of the crashes involved vehicles turning left in and out of the driveways across two or more lanes adjacent to the intersection. After considering several safety engineering improvement options, construction of a raised median along N. Lamar Boulevard from south of Rundberg Lane up to Rutland Drive north, was selected as the most effective and feasible option to address the identified safety issues. A pedestrian signal (pedestrian hybrid beacon) was constructed on Rutland Drive, west of North Lamar Boulevard and a traffic signal was constructed on Rundberg Lane, west of North Lamar Boulevard. The raised median would prevent the risky left-turns in and out of the driveways adjacent to the intersection. The new traffic signal and pedestrian signal on Runberg Lane and Rutland Drive respectively would facilitate safer left-turns in and out of the adjacent businesses. Figure 4 below shows the improvements completed at and adjacent to the intersection of N. Lamar Boulevard and Rundeberg Lane. Figure 5 presents the comparison of 'before' and 'after' conditions at N. Lamar Boulevard / Rundberg Lane.

Figure 4: Project Location: N. Lamar Boulevard / Rundberg Lane North in Austin, Texas

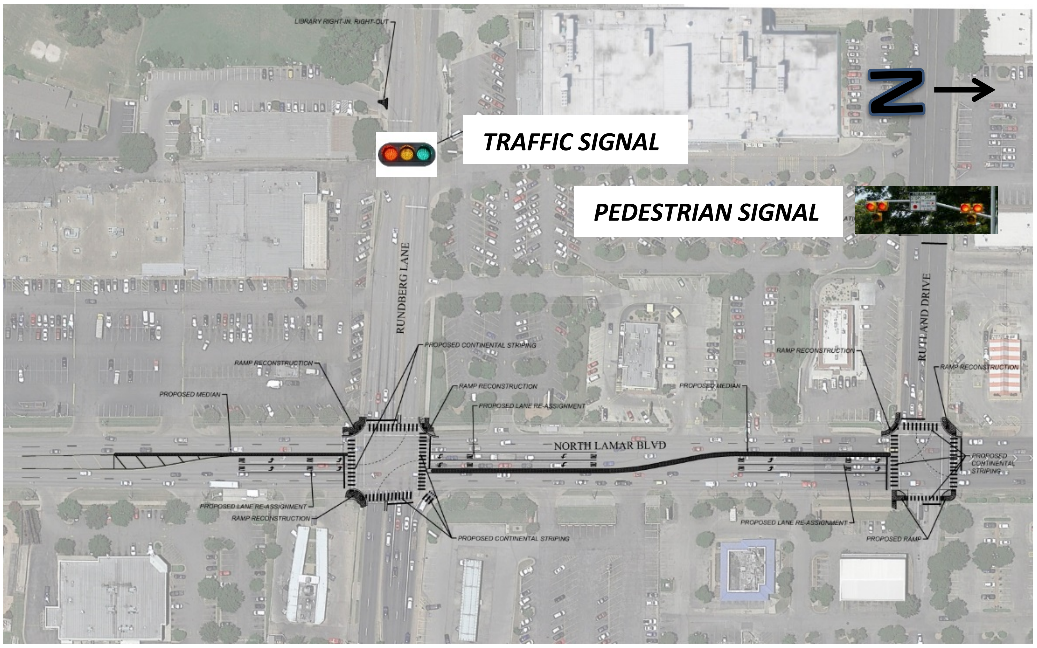

Figure 5: N. Lamar Boulevard / Rundberg Lane: Before and After Conditions

Before Condition **After Condition**

Effectiveness of Safety Improvements at North Lamar Boulevard / Rundberg Lane

In order to assess the effectiveness of the safety improvements implemented at this intersection, 'before' and 'after' crash data were collected from Austin Police Department. The table (Table 3) below shows the comparison of crash statistics before and after the safety improvements are implemented.

Table 3: Before-and-After Crash Statistics at N. Lamar Boulevard / Rundberg Lane

Before Period	**Severe Crashes**	**Total Crashes**
Jun 2016 - May 2017	2	62
Jun 2015 - May 2016	2	59
Jun 2014 - May 2015	3	52
Jun 2013 - May 2014	0	50
Jun 2012 - May 2013	2	47
Annual Frequency	1.8	54
Construction of Safety Improvements	**End of May**	
After Period	**Serious Injury Crashes**	**Total Crashes**
After (June 2017 - March 2018)	0	36
Annual Frequency	0	43.2
Percent Reduction	**100%**	**20.4%**

The before-and-after crash data shows that the raised median effectively reduced the number of total crashes (including intersection crashes) by 20.4% and severe (fatal and serious injury) crashes by 100%.

Again, applying Empirical Bayes (EB) method to account for the yearly fluctuation in crashes (regression to mean bias), the true effectiveness of the safety improvements was calculated. Similar methodology and equations were applied from Highway Safety Manual as illustrated in case of N. Lamar Boulevard / Parmer Lane intersection. The results showed that the safety improvements implemented at the study intersection effectively reduced the overall crash risks by 32% and severity risks by 100%.

Table 4: Effectiveness of Safety Improvements at N. Lamar Boulevard / Rundberg Lane

Safety Effectiveness	**Reduction in Severe Crashes**	**Reduction in Total Crashes**
Raw Annual Reduction	100%	20.4%
Effective Reduction Applying Empirical Bayes Method	100%	32%

SAFETY IMPROVEMENTS AT IH-35 SERVICE ROAD / MARTIN LUTHER KING JR. BOULEVARD

The diamond interchange of IH-35 and Martin Luther King (MLK) Jr. Boulevard is comprised of two intersections at IH-35 Service Road (southbound) / MLK Jr. Blvd and IH-35 Service Road (northbound) / MLK Jr. Blvd. In the crash analysis, couple of clusters of crashes were identified that attributed to the lane configuration, geometry and offset on southbound IH-35 Service Road at MLK Jr. Blvd. Patterns of crashes also involved westbound to southbound left-turning vehicles colliding with eastbound through vehicles, and eastbound to northbound left-turning vehicles colliding with westbound through vehicles. Different safety improvement options were explored to address the patterns of crashes identified. Barua et al. (2010) found that removal of offset at an intersection significantly reduces fatality risks and improves safety. After considering different improvement options, southbound IH-35 Service Road was reconfigured at MLK Jr Blvd reconstructing the south leg of the intersection. East and westbound left-turns were re-phased from protected-permitted to protected-only. Raised pedestrian cross-walks were also constructed at two quadrants of the intersections.

Effectiveness of Safety Improvements at IH-35 Service Road / MLK Jr. Boulevard

'Before' and 'after' crash data were collected to assess the safety effectiveness of the improvements implemented at this intersection. The table (Table 5) below shows the comparison of crash statistics before and after the safety improvements are implemented.

Table 5: Before-and-After Crash Statistics at IH-35 Service Road / MLK Jr. Boulevard

Before Period	**Severe Crashes**	**Total Crashes**
Nov 2015 - Oct 2016	0	16
Nov 2014 - Oct 2015	0	22
Nov 2013 - Oct 2014	0	17
Nov 2012 - Oct 2013	4	63
Annual Frequency	1.0	29.5
Construction of Safety Improvements	**End of October**	
After Period	**Serious Injury Crashes**	**Total Crashes**
After (Nov 2016 - Mar 2018)	0	19
Annual Frequency	0	13.4
Percent Reduction	**100%**	**54.5%**

The before-and-after crash data shows that the safety improvements implemented at IH-35 Service Road / MLK Jr. Blvd effectively reduced overall crashes by 54.5% and severe (fatal and serious injury) crashes by 100%.

Again, using Empirical Bayes (EB) method to account for the yearly fluctuation in crashes (regression to mean bias), the true effectiveness of the safety improvements was calculated applying the methodology contained in Highway Safety Manual. The results showed that the safety improvements implemented at IH-35 Service Road / MLK Jr. Blvd effectively reduced the overall crash risks by 53% and severity risks by 100%.

Table 6: Effectiveness of Safety Improvements at IH-35 Service Road / MLK Jr. Boulevard

Safety Effectiveness	Reduction in Severe Crashes	Reduction in Total Crashes
Raw Annual Reduction	100%	54.5%
Effective Reduction Applying Empirical Bayes Method	100%	53%

SAFETY IMPROVEMENTS AT SH 183 SERVICE ROAD / CAMERON ROAD AND SLAUGHTER LANE / MANCHACA ROAD

Safety improvement project at SH 183 Service Road / Cameron Road has recently been completed. However, a before-and-after study hasn't been completed yet, as it is too early to come to a valid conclusion on the effectiveness of the safety improvements. The other intersection, Slaughter Lane / Manchaca Road is currently under construction. Once this project is complete and significant 'after' data is available, before-and-after studies would be completed for these projects using the Empirical Bayes method.

CONCLUSION

Following a record number of fatalities on Austin roads in 2015, Austin Transportation Department established Transportation Safety Improvement Program to address high priority safety issues with safety engineering countermeasures, to reduce fatal and serious crashes on roads. Transportation Safety Improvement Program planned, designed, and constructed safety engineering improvements at five high priority intersections with fund allocated by the Austin City Council. The safety engineering improvements implemented at the intersections to reduce serious crashes included geometric changes such as revision of lane configuration and alignment removing off-sets, construction of right-turn island / pedestrian refuge, 'smart' right-turns, and raised median to provide access management at the intersection approaches as well as additional traffic signals, pedestrian signals, and warning flashers. After completion of these safety improvements, Austin Transportation Department conducted before-and-after studies using Empirical Bayes Method accounting for the annual fluctuation in crashes (regression to mean bias). The results showed significant reduction in crashes at the treated intersections. Preliminary results revealed an annual overall crash reduction of 21 to 56 percent at these intersections. With respect to reduction in severe crashes, the results came out even better; the safety engineering countermeasures were found to effectively reduce severity risks at the intersections by 40 to 100 percent. These robust results dictate the great success of the safety engineering techniques applied in planning, design and construction at the high priority intersections.

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