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Original Research Paper

Safety effectiveness of roadway conversion with a two way left turn lane

Subasish Das [a,*], Xiaoduan Sun [b], Karen Dixon [a], M. Ashifur Rahman [b]

[a] Texas A&M Transportation Institute, Texas A&M University, College Station, TX 77843, USA
[b] Department of Civil Engineering, University of Louisiana at Lafayette, Lafayette, LA 70502, USA

HIGHLIGHTS

- Addition of a two way left turn lane on four-lane undivided roadways (by restriping) improves safety.
- The crash reduction ranges from 16% to 65%.
- The benefit-cost ratio of this conversion ranges from 97 to 379.
- Low volume urban roadways with less driveways are the best locations for this conversion.

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ABSTRACT

In urban or suburban areas with a large number of access points, four-lane undivided highways are prone to crashes due to left-turning and through movements in a single lane. Many studies recommended expensive countermeasures like conversion from undivided to divided road with physical separation. One inexpensive alternative is reconfiguring the existing roadways by either increasing or decreasing the number of lanes. This study investigated the safety impact of converting four lane undivided roadways (4U) to five lane undivided roadways (5T) with a two way left turn lane (TWLTL). This study used Empirical Bayes method to determine the safety impact of this inexpensive countermeasure. In this study, data from eight sites from Louisiana were collected for investigation, and site-specific crash modification factor (CMF) values were calculated. Although 5T is usually not preferable due to its exposure of higher number of crashes in the existing literature, the findings of the current study indicated a positive safety impact. The benefit-cost ratio of this conversion ranges from 97 to 379. The current findings indicate that conversion of 4U to 5T is a feasible inexpensive solution for urban roadways with lower volume and a limited number of driveways.

* Corresponding author. Tel.: +1 979 845 9958; fax: +1 979 845 6006.
E-mail addresses: s-das@tti.tamu.edu (S. Das), xsun@louisiana.edu (X. Sun), k-dixon@tti.tamu.edu (K. Dixon), ashifur@outlook.com (M.A. Rahman).

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1. Introduction

Four-lane undivided highways in the urban and suburban area become more crash prone with the increase of traffic volume and turning movements. Since the inside lane is used by both high speed through traffic and slow speed left turning traffic, rear-end crashes occur as a result of speed differentials or, in some cases, stopped cars in the active travel lane. Due to increases in roadside development in urban and suburban areas, it is a challenge for transportation engineers and safety specialists to improve the safety of four lane undivided highways. In Louisiana, there are 1530 miles of undivided multilane roadways and most of them are four lane highways on the state Department of Transportation and Development System (LADOTD). 93% of these roadways are in urban and suburban areas. A total 8498 crashes occurred on urban four lane undivided highways in 2014, where 40% of the crashes are rear-ended crashes. A study on this particular safety problem is thus called for. One of important task of safety analysis is to identify appropriate treatment or countermeasure for risk mitigation and safety improvement.

The desirable option to improve safety performance is installing physical separation either by a barrier or by green space (Boulevard). The key constraint to the countermeasure is that it requires significant resources. Converting four lane undivided urban highway to a five lane highway with a two way left turn lane (TWLTL) by restriping is one inexpensive solution to the problem. Narrowing lane width to accommodate a TWLTL separates turning vehicles from through vehicles without reducing the capacity, provided that there is sufficient width. However, this lane conversion is not a very popular solution. Louisiana has policies that discourage the five lane highway design with TWLTL in the construction of new roads.

The aim of this study is to investigate the safety impact of converting four lane undivided roadways (4U) to five lane undivided roadways (5T) with a TWLTL using Empirical Bayes method.

2. Literature review

There are very few studies on the safety benefits of this particular type of lane conversion. The AASHTO Highway Safety Manual (AASHTO, 2010) documented several crash modification factors (CMF) but did not provide any crash modification factor (CMF) to evaluate the effectiveness of this reconfiguration to any type of roadways. The TRB access management manual (TRB, 2014) and NCHRP report 420 (Gluck et al., 1999) included access management issues like TWLTL thresholds. A national cooperative highway research program (NCHRP) report stated that conversion from a four lane undivided cross section to a five lane TWLTL cross section with narrower lanes reduced crash rates, on the average, by 45% (Harwood, 1990). This study was further reinforced by a collision study which reported at least 50% less rear-end crash proportion in five lane TWLTL than rear-end crash proportion in four-lane undivided highway (McCormick and Wilson, 1983). In recent years, Sun et al. (2013) used evaluated effectiveness of 4U to 5T conversions in Louisiana. The findings showed that the CMFs for both roadways are estimated to be less than 0.50 with a standard deviation less than 0.07. Another study in Louisiana estimated CMF (Sun and Das, 2013a, b) for converting a four lane undivided highway to a five lane highway to be 0.60, which indicates a 40% crash reduction due to this countermeasure implementation. This study used only four sites to perform the analysis, which requires additional research with more sites.

Since there is limited literature regarding this conversion, the comparison between four lane undivided highway and five lane highway with TWLTL under the same condition is another approach to explore its safety benefits. The Minnesota Statewide Urban Design and Specifications (IOWADOT, 2010) lists the crash rate of 6.75 for four lane undivided roadway and 4.01 for five lane with center turn lane. The results were based on a Minnesota study estimated the statewide crash rate of urban four lane undivided highway with no left turn lane as 5.3 per million vehicle miles traveled and urban four lane undivided highway with TWLTL as 4.6 per million vehicle miles traveled (Preston et al., 1998).

A comparison was made between four lane undivided roadway and five lane with TWLTL roadway to see the design alternatives in Oklahoma in 2007. It was found that five lane with TWLTL roadway is more advantageous in reducing rear-end and head-on crashes compared to four lane undivided roadway. This comparison was used to evaluate US 81 for improvement along with an approximate 30-mile segment (ODOT, 2007), although safety benefit was not one of the key criteria.

In recent years, there were many studies on conversion of urban four lane to three lane roadway with a TWLTL in the center (Huang et al., 2002; Knapp et al., 2014; Pawlovich et al., 2006; USDOT, 2010, 2016). This conversion is also known as "road diet". This conversion has a proven safety record with some limitations. According to Federal Highway Administration (FHWA). this conversion is suitable for annual average daily traffic (AADT) less than 20,000 (USDOT, 2010). Some studies reported, an increase in rear-end crashes due to speed differential in through traffic and right turn traffic, increased delay and increased travel time. In the city of Grand Rapids, Michigan, it has been reported that, after road diet, rear-end crashes nearly tripled after installation with longer travel times (average increase of 19–52 s through corridor) and additional delay (USDOT, 2016). All these limitations can apparently be overcome by four lane to five lane with TWLTL conversion, since it utilizes the road width to accommodate left turn lane, through lane, and right turn lane.

3. Selected sites

The 5T (five lane roadways with a TWLTL) roadways are considered as a common multilane design alternative for urban and suburban arterial roadways with a limited number of driveways. It has two through lanes in each direction and a center lane (usually less wide than the travel lanes) dedicated for left turn maneuvers for the access to driveways and minor intersections. Using a TWLTL encourages more business opportunities in the urban areas (Das, 2015). The research team selected eight sites from Louisiana to perform this analysis. Table 1 lists general site information of the selected sites.

One key issue in this current countermeasure is the reduction of the lane widths. The average reduction of the lane widths is around 2 ft. Four of the studied sites have lane width over 10 ft. in the 5T conversion. The other sites have approximately 9 ft. width. Fig. 1 illustrates the roadway sections of the sites (the distances are not measured by scales).

Table 2 lists the AADT and observed crashes in the before and after years for the sites. The traffic volume ranges from 6833 to 27,467 (mean is 19,148 and standard deviation is 5800) in the before years. The after year traffic volumes range from 7900 to 27,000 (mean is 19,760 and standard deviation is 5765). Site 3 shows maximum volume increase (around 15%), and site 2 shows highest crash reduction (around 60%). Majority of the roadways have AADT value more than 14,000 vpd (except site 3).

Fig. 2 shows the locations of the implementation sites for 4U to 5T conversion. All of sites are located at the south west region of Louisiana.

4. Observational before-after study

Observational before-after study is the common approach in determining the effectiveness of roadway countermeasures. There are several before-after observational studies in practice. In designing before-after studies, two key issues are needed to be considered. First, determination of sample size depends on the magnitude of the treatment effect and the precision of the estimate. Precision of the estimate usually increase with a larger sample size. It is important to note that getting a larger number of sample sites is not always feasible. Second, the changes of crashes at treated sites in the after years are not necessarily independently dependent on countermeasure. It may happen due to other factors, for example, traffic volume changes or regression-to-the-mean. The common approaches are: 1) naïve before after study, 2) improved prediction method, 3) comparison group method, 4) empirical Bayes method, 5) full Bayes method, and 6) difference-in-difference (DID) method. Fig. 3 shows the concepts behind before-after observational studies.

Table 1 – Site information.

Site	Roadway	Parish	District	Length (mile)
1	LA 14	Lafourche	2	0.25
2	LA 14	Lafourche	2	0.42
3	LA 14	Vermilion	3	0.47
4	LA 14 Bypass	Vermilion	3	0.67
5	LA 3025	Lafayette	3	1.23
6	LA 182	St. Landry	3	0.15
7	LA 28	Rapides	8	0.40
8	LA 1138	Calcasieu	7	0.79

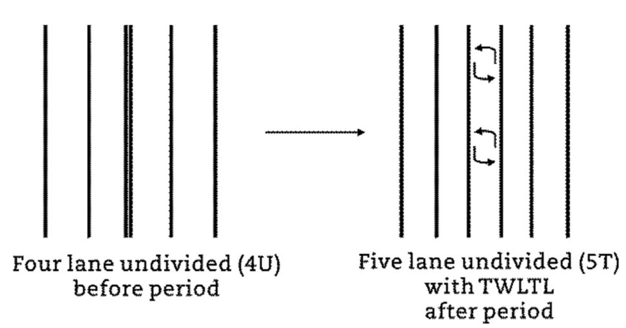

Fig. 1 – Schematic roadway sections (Das, 2015).

4.1. *Empirical Bayes (EB) method*

Robinson (2017) explained in his new book empirical Bayes (EB) offers "shortcuts" that allow easy computation at scale. Full Bayesian methods that use Markov Chain Monte Carlo (MCMC) are useful when performance is less important than accuracy, such as analyzing a scientific study. However, production systems often need to perform estimation in a fraction of a second, and run them thousands or millions of times each day. Empirical Bayesian methods, such as the ones we discuss in this book, can make this process easy." Bayesian analysis depends on a prior distribution for the model parameters. This prior, either parametric or nonparametric in nature, depends on unknown parameters. This sequence of parameters and priors develops the framework of a hierarchical model. The ultimate goal is the stopping point of the hierarchy with all remaining prior parameters assumed known (Carlin and Louis, 1996). The EB method uses the observed data to estimate these final stage parameters and then proceeds as though the prior are known, which makes the computation easy to interpret.

The objective of the empirical Bayes (EB) methodology is to estimate the number of crashes that would have occurred at an individual treated site in the after years had a treatment not been implemented. This method accounts for the effect of regression-to-the-mean, changes in traffic volume and other potential changes in the roadway features during the before and after time periods (Sun et al., 2014). In accounting for regression-to-the-mean, the number of crashes expected in the before period without the treatment ($N_{predicted,t,b}$) is a weighted average of information from two sources:

- The number of crashes observed in the before period at the treated sites ($N_{observed,t,b}$).
- The number of crashes predicted at the treated sites based on reference sites with similar traffic and physical characteristics ($N_{predicted,t,b}$).

To estimate the weights and the number of crashes expected on sites with similar traffic and physical characteristics, safety performance function (SPF) for urban roadways was used. An SPF is a statistical model that predicts the mean crash frequency for similar locations with the same characteristics. These characteristics typically include traffic volume and may include other variables such as traffic control and significant geometric characteristics. This SPF is used to derive the second source of information for the empirical Bayes estimation which is the number of crashes predicted at

Table 2 – AADT and observed crashes in before and after years.

Site	Before period			After period		
	Years	AADT (vpd)	Total crashes	Years	AADT (vpd)	Total crashes
1	2004–2006	19,867	21	2008–2010	19,767	9
2	2004–2006	19,867	118	2008–2010	19,767	47
3	2008–2010	6833	39	2012–2014	7900	20
4	2008–2010	19,200	126	2012–2014	21,000	114
5	2000–2002	23,888	358	2004–2006	26,580	148
6	2004–2006	21,367	65	2008–2010	21,100	51
7	2002–2004	27,467	116	2006–2008	27,000	75
8	1996–1998	14,693	115	2000–2002	14,967	79

treated sites based on sites with similar operational and geometric characteristics ($N_{predicted,t,b}$). Many safety studies have used EB method as an appropriate effectiveness measurement technique (Das et al., 2017; Gross et al., 2010; Huang et al., 2009; Miller et al., 2006; Persaud et al., 2001; Sun and Das, 2013a, b; Wang et al., 2017; Wu et al., 2015; Yang and Loo, 2016). The calculation method of this current followed the steps used in Hauer's studies (Hauer, 1997, 2015).

Step 1: Evaluate the predictive values.

The predictive models for urban and suburban arterial roadway segments are presented in the following equations in the highway safety manual (HSM)

$$N_{predicted} = C_L(N_{rs} + N_{ped} + N_{bike}) \quad (1)$$

$$N_{rs} = N_{spfrs}(CMF_1 \times \cdots \times CMF_n) \quad (2)$$

$$N_{spfrs} = N_{sv} + N_{mvnd} + N_{mvd} \quad (3)$$

where $N_{predicted}$ is the predicted average crash frequency of an individual roadway segment for the selected year, N_{rs} is the predicted average crash frequency of an individual roadway segment (excluding vehicle-pedestrian and vehicle-bicycle collisions), N_{spfrs} is the predicted total average crash frequency

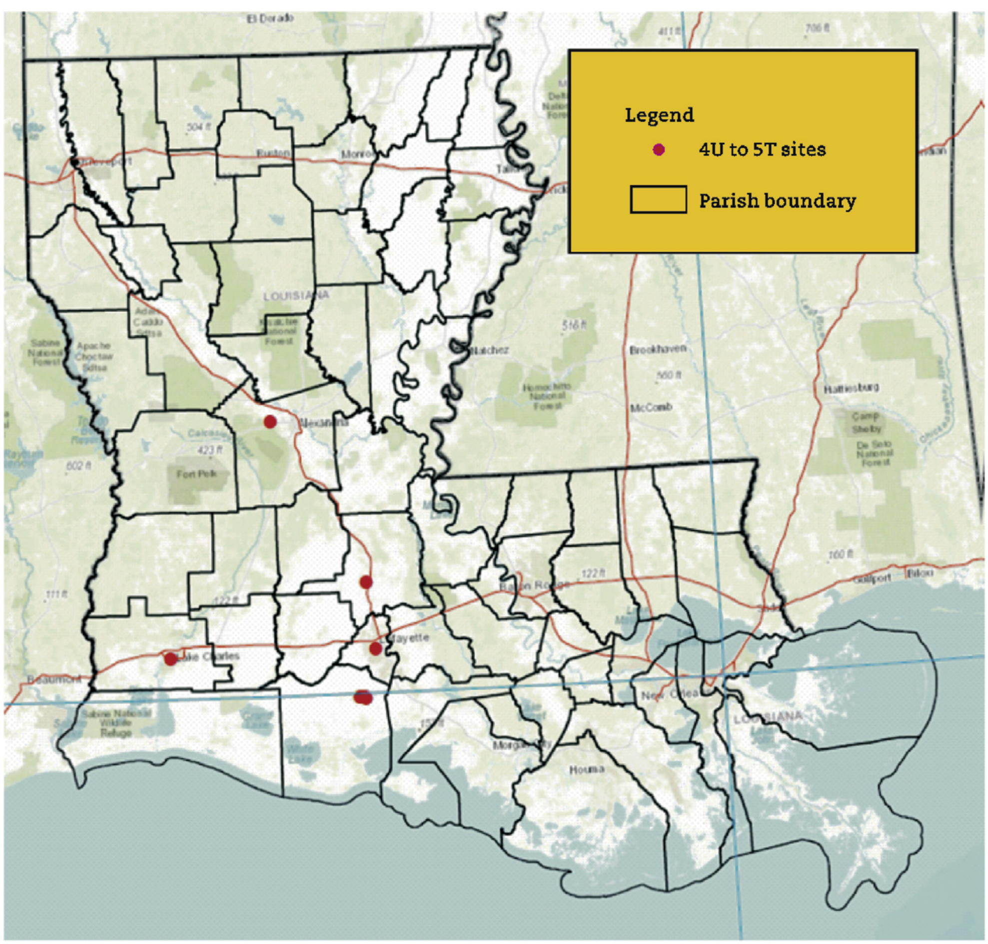

Fig. 2 – 4U to 5T conversion sites.

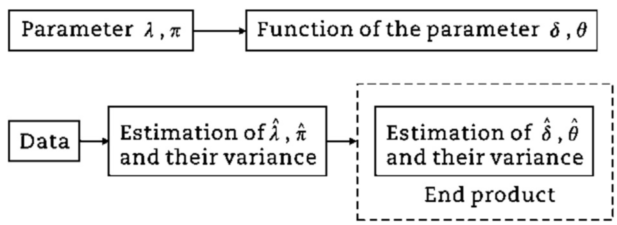

Fig. 3 – Concept of observational before-after studies (Das, 2015).

of an individual roadway segment for base conditions (excluding vehicle-pedestrian and vehicle-bicycle collisions), N_{ped} is the predicted average crash frequency of vehicle-pedestrian collisions for an individual roadway segment, N_{bike} is the predicted average crash frequency of vehicle-bicycle collisions for an individual roadway segment, $CMF_1 \times \cdots \times CMF_n$ is the crash modification factors for roadway segments, C_L is the calibration factor for urban and suburban roadway segments in Louisiana, N_{sv} is the predicted average crash frequency of single-vehicle crashes for base conditions, N_{mvnd} is the predicted average crash frequency of multiple-vehicle non-driveway collisions for base conditions, N_{mvd} is the predicted average crash frequency of multiple-vehicle driveway-related collisions.

The SPF for single vehicle crashes and multiple-vehicle non-driveway collisions use the following equation

$$N_{sv} = \exp[a + b\ln(\text{AADT}) + \ln(L)] \tag{4}$$

$$N_{mvnd} = \exp[a + b\ln(\text{AADT}) + \ln(L)] \tag{5}$$

where AADT is the average annual daily traffic volume (veh/d) on roadway segment, L is the length of roadway segment (mile), and a, b are the regression coefficients (from the HSM AASHTO, 2010, and AASHTO, 2010).

The total number of multiple-vehicle driveway-related collisions within a roadway segment is determined as

$$N_{mvd} = \sum_{\substack{\text{all} \\ \text{driveway} \\ \text{types}}} n_i N_i \left(\frac{\text{AADT}}{15000}\right)^t \tag{6}$$

where N_i is the number of driveway-related collisions per driveway per year for driveway type i from Table 3, n_i is the number of driveways within roadway segment of driveway type i including all driveways on both sides of the road (Table 3), and t is the coefficient for traffic volume adjustment (acquired from the HSM) from Table 3.

The number of driveways in all of the sites ranges from 11 to 54. It is also important to note that none of these sites have major commercial or residential driveways. The research team has considered other CMFs as 1 to determine N_{rs}.

$$N_{rs} = N_{spfrs} \times (1 \times \cdots \times 1) = N_{sv} + N_{mvnd} + N_{mvd} \tag{7}$$

C_L value is considered as 1 in this current study.

$$N_{predicted} = 1 \times (N_{rs} + N_{ped} + N_{bike}) = N_{rs} + N_{ped} + N_{bike} \tag{8}$$

The number of vehicle-pedestrian collisions per year for a roadway segment is estimated as

$$N_{ped} = N_{rs} f_{ped} \tag{9}$$

where f_{ped} is the pedestrian crash adjustment factor (from the HSM AASHTO, 2010).

The number of vehicle-bicycle collisions per year for a roadway segment is estimated as

$$N_{bike} = N_{rs} f_{bike} \tag{10}$$

where f_{bike} is the pedestrian crash adjustment factor (from the HSM AASHTO, 2010).

Table 4 lists the predicted and expected values of the crashes from this method.

Step 2: evaluate the expected values.

The empirical Bayes estimates the expected number of crashes without treatment. $N_{expected,t,b}$ is computed from the following equation

$$N_{expected,t,b} = wN_{predicted,t,b} + (1 - w)N_{observed,t,b} \tag{11}$$

$$w = \frac{1}{1 + k \sum_{\text{all study years}} N_{predicted}} \tag{12}$$

where w is the weighted adjustment to be placed on the predictive model estimate, k is 0.236/Segment length which equal to over dispersion parameter of the associated SPF used to estimate $N_{predicted}$.

The negative binomial regression used in the SPF allows the variance to differ from the mean through the incorporation of an additional parameter called the dispersion parameter. When the variance is greater than the mean, the data is known to be over dispersed. The over dispersion parameter has positive values. It is important to note that with the increment of over dispersion parameter, the weighted adjustment factor decreases. In general, more emphasis is placed on the observed/reported crashes rather than the SPF predicted crash frequency. The formula used for k is acquired from the HSM.

Table 3 – Driveway densities in each site.

Driveway type	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	t for 4U	t for 5T
Major commercial	0	0	0	0	0	0	0	1	0.182	0.165
Major residential	0	1	0	1	0	0	0	0	0.096	0.087
Major industrial	0	0	0	0	0	0	0	0	0.198	0.181
Minor commercial	11	15	15	29	24	5	28	50	0.058	0.053
Minor residential	0	0	19	5	30	8	2	2	0.018	0.016
Minor industrial	0	1	0	0	0	0	0	0	0.026	0.024

Table 4 – Predicted and expected values using EB method.

Site	Observed crashes before years $N_{observed,t,b}$	Observed crashes after years $N_{observed,t,a}$	Predicted crashes before years $N_{predicted,t,b}$	Predicted crashes after years $N_{predicted,t,a}$	Expected crashes before years $N_{expected,t,b}$	Expected crashes after years $N_{expected,t,a}$	Var ($N_{expected,t,a}$)
1	21	9	2.24	2.95	13.51	17.85	13.79
2	118	47	3.64	4.85	83.82	111.54	103.59
3	39	20	1.47	2.19	21.00	31.27	23.79
4	126	114	6.72	8.73	103.28	134.18	140.54
5	358	148	14.04	18.27	323.00	420.40	490.79
6	65	51	1.61	2.07	33.30	42.67	27.14
7	116	75	6.43	7.86	93.23	113.98	110.00
8	115	79	6.08	7.99	92.73	121.86	126.81

The adjusted value of the EB estimate, $N_{expected,t,a}$ is the expected number of crashes in the after years without treatment and is calculated as follow

$$N_{expected,t,a} = N_{expected,t,b}\frac{N_{predicted,t,a}}{N_{predicted,t,b}} \tag{13}$$

The variance of $N_{expected,t,a}$ is

$$\mathrm{Var}(N_{expected,t,a}) = N_{expected,t,a}\frac{N_{predicted,t,a}}{N_{predicted,t,b}}(1-w) \tag{14}$$

Step 3: evaluate the CMF and variance of CMF.

The CMF and its variance can be calculated from the following equations

$$\mathrm{CMF} = \frac{N_{observed,t,a}/N_{expected,t,a}}{1+\left[\mathrm{Var}(N_{expected,t,a})/N^2_{expected,t,a}\right]} \tag{15}$$

$$\mathrm{Var(CMF)} = \mathrm{CMF}^2\frac{1/N_{observed,t,a}+\left[\mathrm{Var}(N_{expected,t,a})/N^2_{expected,t,a}\right]}{\left[1+\mathrm{Var}(N_{expected,t,a})/N^2_{expected,t,a}\right]^2} \tag{16}$$

In place of doing an explanatory analysis, this study used robust observational study EB method to show that the reductions are consistent in the after years. For example, site 6 (Table 5) shows a CMF of 1.18 (18% crash increase for 5T), but the observed crashes in the after years is lower than before years. EB method considers both crash counts and SPF to provide a better estimate by removing bias due to regression to mean. Table 5 enlists the values of site specific CMF, standard deviations, and 95% confidence interval (CI) of the CMF from this method. The CMF values range from 0.35 to 0.84 (except site 6; in which CMF is greater than 1). The 95% values are lower than 1 in most cases except in site 4, and site 6.

Table 5 – CMF and variance of CMF values.

Site	CMF	Var (CMF)	Sd (CMF)	95% CI of CMF
1	0.48	0.03	0.18	(0.13, 0.84)
2	0.42	0.01	0.07	(0.28, 0.56)
3	0.62	0.03	0.17	(0.30, 0.95)
4	0.84	0.01	0.11	(0.63, 1.05)
5	0.35	0.00	0.03	(0.28, 0.42)
6	1.18	0.05	0.22	(0.76, 1.60)
7	0.65	0.01	0.10	(0.47, 0.84)
8	0.64	0.01	0.09	(0.46, 0.82)

Fig. 4 shows SPF graphics for multiple vehicle non-driveway crashes. A similar graphic (Fig. 5) for different driveway densities was reproduced by another study (Das, 2015). In both cases, predicted crashes for 5T are higher in numbers. For example (Fig. 4), for AADT value 40,000 vpd, the predicted crashes of 5T is nearly 15 (higher compared to 4U, which is approximately 12). Similarly, Fig. 5 values also indicate that 5T associate with higher predicted crashes than 4U. However, this study shows that implementation of 5T improves safety in the studied sites in Louisiana. The crash reduction in seven sites ranges from 16% to 65%, which indicates that urban roadways with lower volume and limited number of non-major driveways can show significant safety improvement with inexpensive countermeasure like lane restriping. Rahman et al. (2018) used lane conversation data from nine sites in Louisiana and found similar findings.

4.2. *Benefit cost analysis*

The cost of re-striping a roadway per mile (including both materials and labor) is about $7105 by the district maintenance crew of the district office or $11,450 by outside contract. To determine the recent cost per injury or PDO crashes, a study by Schneider (2015) is consulted. In that study, cost estimates are based on a study conducted by NHTSA in 2000 and these values were adjusted by the cost

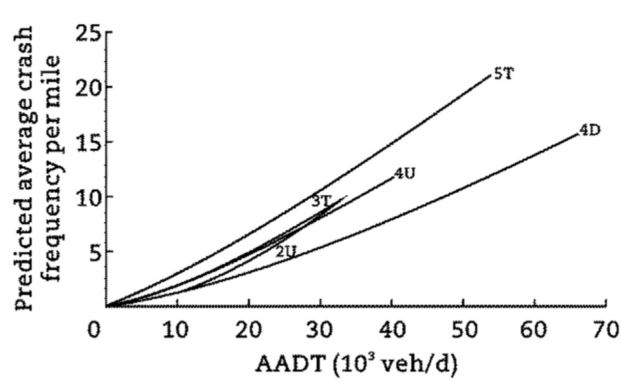

Fig. 4 – SPF graphics for multiple vehicle non-driveway collisions (AASHTO, 2010).

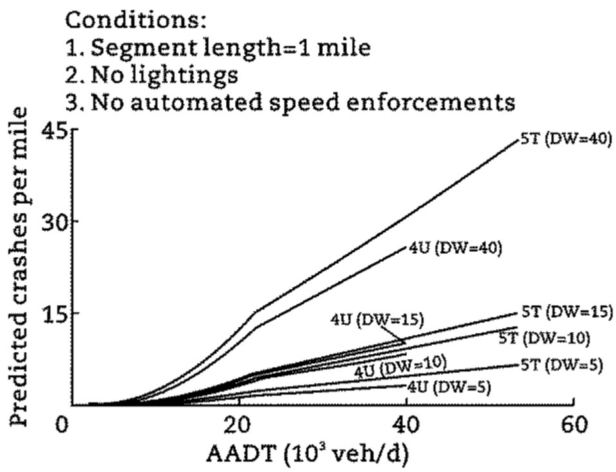

Fig. 5 – Multiple-vehicle driveway-related predicted crashes per mile (Das, 2015).

performance index (CPI) to obtain costs for 2014. The benefit cost ratio for the treatment sites range from 97 to 379. The benefit-cost ratio for all eight segments is shown in Table 6. The B/C ratio was calculated based on the observed crash reduction. Site 6 has a higher CMF due to surroundings and other variables. Site 6 has 14 crash reductions in the after years. If the crashes associate with higher injury, the benefit would be higher. It is important to note that the benefit-cost analysis should consider consumer surplus, inflation, and prorated value to facility service life-cycle. As the B/C ratio is very high (97 and above), the authors did not proceed to perform analysis to evaluate a precise B/C ratio. The authors consider this analysis as a future investigation.

In Table 6 the B/C ratio was calculated based on the observed crash reduction. Site 6 has a higher CMF due to surroundings and other variables. Site 6 has 14 crash reductions in the after years. If the crashes associate with higher injury, the benefit would be higher. It is important to note that the benefit-cost analysis should consider consumer surplus, inflation, and prorated value to facility service life-cycle. As the B/C ratio is very high (97 and above), the authors did not proceed to perform analysis to evaluate a precise B/C ratio. The authors consider this analysis as a future investigation.

Table 6 – Benefit cost ratio.

Site	Total benefits ($)	Total cost ($)	B/C ratio
1	278,951	2863	97
2	1,387,818	4809	289
3	810,675	5382	151
4	1,142,767	7672	149
5	3,039,771	14,084	216
6	651,252	1718	379
7	630,598	4580	138
8	1,076,223	9046	119
PDO crash cost ($)	6623		
Injury crash cost ($)	46,518		
Cost per mile ($)	11,450		

5. Conclusions

The study demonstrates that 4U to 5T conversion on urban roads can be very beneficial. This study has two particular contributions:

- It evaluates the effect of lane conversion on eight different sites in Louisiana. The safety improvement is consistent for most of the sites. Empirical Bayes analysis shows an expected crash reduction up to 52% with only one site with the possible crash increase. The benefit cost ratio is very promising, ranges from 97 up to 379. It is important to note that the studied sites have a limited number of non-major driveways and moderate (around 20,000 vpd) traffic volume.
- It shows clear differences between the HSM findings and the current findings. HSM suggests that 5T would associate with a higher number of crashes. In contrary, this study shows the opposite result. It may due to the local conditions of the current sites. A database with higher sample size can be tested in future for more robust comparison.

When the required options are restricted in an instantaneous application, it is better to do something that can reduce crashes than passively wait for future, possibly unrealistic, opportunities. This study suggests that inserting a two way left turn lane on four lane undivided urban highways can have significant benefit. Changing four-lane undivided roadway segment to a roadway type that is not used in new construction proves to be a very effective crash countermeasure. There are two major limitations of the current study: 1) it does not examine the effect of pavement width in the SPF and, 2) traffic conversions are not considered in the EB calculation. Additionally, the sample size is not big enough to draw a universal conclusion. Future studies can consider developing roadway specific SPFs for Louisiana and evaluate the effectiveness with large sample size. This study used the HSM equations and related values to determine the safety impact of 4U to 5T conversion.

With available funds in the future, it is easy to convert these five-lane roadway segments to a Boulevard roadway type-an expensive and time-consuming concept that is promoted today in urban and suburban areas in Louisiana. However, it is also important to note that one-size-fits-all solutions do not usually work in highway safety issues. Moreover, the safety improvement of 4U to 5T is limited to lower volume and a limited number of non-major roadways. Caution must be taken when applying this safety countermeasure in other locations.

Conflicts of interest

The authors do not have any conflict of interest with other entities or researchers.

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Dr. Subasish Das is an associate transportation researcher at Texas A&M Transportation Institute (TTI). He received his PhD in civil engineering from University of Louisiana at Lafayette in 2015, and holds a Master of Science in civil engineering from the same university in 2012. He has more than 8 years of national and international experience associated with transportation safety engineering research projects. His primary fields of research interest are roadway safety, roadway design, and associated operational issues. Dr. Das is the author or co-author of over 40 technical papers or research reports.

Dr. Xiaoduan Sun, P.E., is the endowed professor of the civil engineering department at the University of Louisiana at Lafayette. Her primary fields of research interest are roadway safety, roadway design, and associated operational issues. Dr. Sun is the author or co-author of over 80 technical papers or research reports.

Dr. Karen Dixon, P.E., is a research engineer and program manager for the Roadway Safety Program at the Texas A&M Transportation Institute. Prior to joining TTI, Dr. Dixon was a professor for the Oregon State University, School of Civil & Construction Engineering, where she was awarded the title of CE excellence faculty fellow. Prior to her appointment at OSU, Dr. Dixon was a tenured associate professor at the Georgia Institute of Technology. Dr. Dixon is a member of the TRB Highway Safety Performance Committee and a member of the TRB Operational Effects of Geometrics Committee. Dr. Dixon served as the chair of the technical research subcommittee for the development of the AASHTO Highway Safety Manual.

M. Ashifur Rahman is continuing his doctoral studies in systems engineering with a concentration in Civil Engineering at the University of Louisiana at Lafayette. He has published several research reports and papers.