SAFETY EVALUATION OF ALL-ELECTRONIC TOLL COLLECTION SYSTEM

TRB 15-2700

Muamer Abuzwidah, and Mohamed Abdel-Aty
Department of Civil, Environmental & Construction Engineering, University of Central Florida, Orlando, Florida

Overview

- Traditional Mainline Toll Plaza (TMTP) is considered the most high risk location on toll roads.
- There is a lack of research that quantifies the safety impacts of the new tolling systems.
- This study evaluated the safety effectiveness of conversion from TMTP or Hybrid Mainline Toll Plaza (HMTP) to All-Electronic Toll Collection (AETC) system.
- Data included all mainline toll plazas in Florida was used in the analysis. And crash data for eleven-year period (2003-2013) was investigated.
- Various observational Before-After studies including the Empirical Bayes method were applied.
- This paper provided an up-to-date safety impact of using different toll collection systems. And proved for the first time the benefits of using AETC system.

Data Preparation

- Data from one hundred sites of mainline toll plazas located on approximately 750 miles of toll roads in Florida was used. These toll plazas were classified based on the type of design (i.e. TMTP, HMTP, or AETC), and whether if the location was a reference site, treated site or the treatment was applied from the beginning.
- Multiple sources of data available online maintained by Florida Department of Transportation (FDOT) were utilized to identify:
  - Locations.
  - Traffic data.
  - Geometric and geographic data.
  - Crash Data.

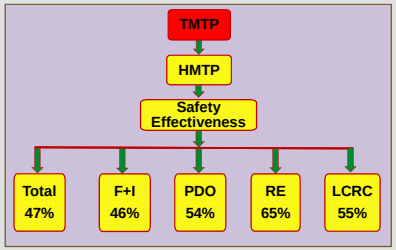
Toll Plaza Types

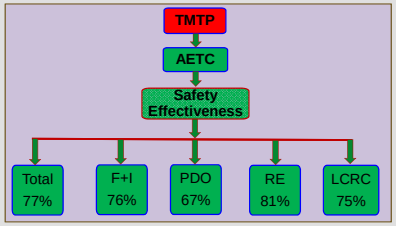
Results

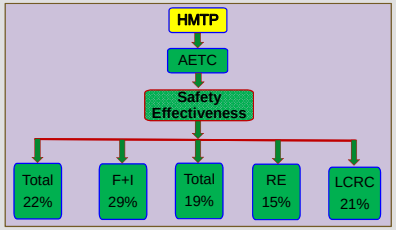
Before-After with the Empirical Bayes								
Crash Category	Upgrade to HMTP *** Previous study		Upgrade to AETC					
	Traditional Toll Plaza as a base case		Traditional Toll Plaza as a base case		Hybrid Toll Plaza as a base case			
	'Full' SPF		'Full' SPF		'Simple' SPF		'Full' SPF	
	CMF S.E.*	Standard Error	CMF S.E.*	Standard Error	CMF S.E.*	Standard Error	CMF S.E.*	Standard Error
Total Crashes	0.53 (47.30%)	0.05 (5.39%)	0.23 (77.30%)	0.07 (7.44%)	-	-	0.78 (22.30%)	0.09 (9.31%)
F+I	0.54 (46.2%)	0.07 (6.62%)	0.24 (76.2%)	0.09 (8.72%)	-	-	0.71 (29.2%)	0.08 (8.12%)
PDO	0.46 (54.2%)	0.06 (6.22%)	0.33 (67.2%)	0.08 (7.92%)	0.81 (19.2%)	0.10 (9.64%)	-	-
Rear End	0.34 (65.6%)	0.06 (6.4%)	0.19 (81.6%)	0.10 (9.83%)	0.84 (15.6%)	0.08 (7.7%)	-	-
LCRC*	0.45 (55.4%)	0.09 (9%)	0.25 (75.4%)	0.07 (7%)	-	-	0.79 (21.4%)	0.10 (9.53%)

S.E.* =Safety Effectiveness = Safety Effectiveness= (1- CMF) *100
LCRC* =Lane change related crashes = (i.e. sideswipe, angle crashes, etc.)
Upgrade to HMTP ***= Source (Abuzwidah et al., 2014).

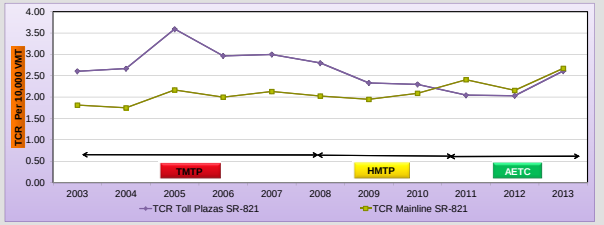
Safety Effectiveness of Treatments







Comparison between crash rates on the mainline of SR- 821 and its toll plazas



Where:
TCR = Total Crash Rate per 10,000 VMT.
TMTP = Traditional Mainline Toll Plaza.
HMTP = Hybrid Mainline Toll Plaza.
AETC = All-Electronic Toll Collection.

Summary and Conclusion

This study evaluated the safety effectiveness of conversion from TMTP or HMTP to AETC system. An extensive data collection was conducted that included hundred mainline toll plazas located on more than 750 miles of toll roads in Florida. Various observational before-after studies including the Empirical Bayes method were applied.

The results indicated that the conversion from the TMTP to an AETC system resulted in an average crash reduction of 77, 76, and 67 percent for total, fatal-and-injury and Property Damage Only (PDO) crashes, respectively; for rear end and Lane Change Related (LCR) crashes the average reductions were 81 and 75 percent, respectively. The conversion from HMTP to AETC system enhanced traffic safety by reducing crashes by 23, 29 and 19 percent for total, fatal-and-injury, and PDO crashes respectively; also, for rear end and LCR crashes, the average reductions were 15 and 21 percent, respectively.

Overall, this paper provided an up-to-date safety impact of using different toll collection systems. The results proved that the AETC system significantly improved traffic safety for all crash categories; and changed toll plazas from the highest risk on Expressways to be similar to regular segments.

Acknowledgements

The authors wish to thank SAFER-SIM for partially funding this research. SAFER-SIM is a RITA funded UTC Center lead by The University of Iowa. We also thank the Florida Department of Transportation (FDOT) for providing the data that were used in this study, and for funding this research. All opinions and results are solely those of the authors.

TRAFFIC SAFETY EVALUATION AND MODELING OF TOLL COLLECTION SYSTEM

TRB 15-2711

Muamer Abuzwidah, and Mohamed Abdel-Aty
Department of Civil, Environmental & Construction Engineering, University of Central Florida, Orlando, Florida

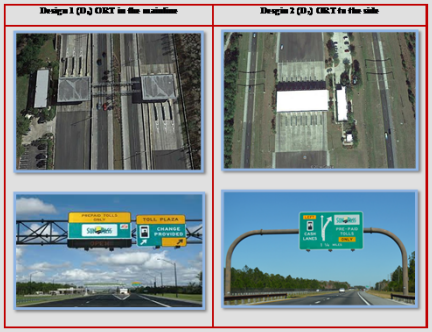
Overview

- This study examines for the first time the traffic safety impact of using different designs of the Hybrid Mainline Toll Plaza (HMTP). HMTP is a plaza combines open road tolling for electronic toll collection and plaza structure for manual payment.
- This study also helps understand the relationship between the crash frequency and several important crash-related factors and circumstances using multiple analytical techniques such as Negative Binomial Regression Model and Log-Linear Models.
- The results of this study proved that there is a significant difference between the different designs of the HMTP. And also indicated significant relationships between the crash frequency and toll plaza types, annual average daily traffic, and driver-age.
- Moreover, this study has also proved that the HMTP and the All-Electronic Toll Collection (AETC) were associated with less number of crashes than the Traditional Mainline Toll Plazas.

Data Preparation

- Crash data from a seven-year period was investigated, and a hundred mainline toll plazas in Florida were evaluated. These toll plazas were classified based on the type of design (i.e. TMTP, HMTP, or AETC).
- Multiple sources of data available online maintained by Florida Department of Transportation (FDOT) were utilized to identify:
  - Locations.
  - Traffic data.
  - Geometric and geographic data.
  - Crash Data.

Comparison between different designs of the hybrid mainline toll plaza



Data

Data from 60 Hybrid Mainline Toll Plazas (HMTP) were used in this approach. Crash data from a three-year period after the implementation of the hybrid mainline toll plaza was investigated.

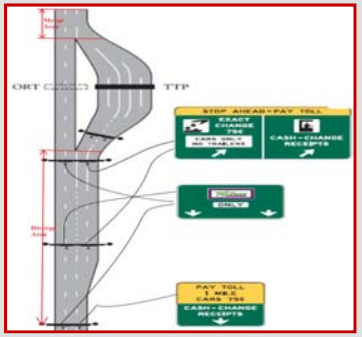
Results

Negative Binomial: Estimates of Coefficients for Different designs of the HMTP

Crash Type	Injury Level	Parameter	Estimates	Pr > ChiSq	AIC
All	All	Intercept	-16.755	<0.0001	168.653
		Log AADT	1.883	<0.0001	
		Design type*	0.169	0.0433	
		Dispersion	0.113		

Design type *= (D1-and-D2) dummy variable (i.e. D1=0 and D2=1.)

Comparison between diverge-and-merge areas at the HMTP



Data

Data from 120 observations was used. Sixty hybrid mainline toll plazas, each one has two locations, one before (Diverge) and one after (Merge) the Toll plaza (60*2=120 observations).

Results

Negative Binomial: Estimates of Coefficients of diverge and merge areas of the HMTP

Crash Type	Injury Level	Parameter	Estimates	Pr > ChiSq	AIC
All	All	Intercept	-20.6811	<0.0001	365.607
		Log AADT	2.2327	<0.0001	
		Location*	0.2103	0.0317	
		Dispersion	2.2667		

Location* = (diverge-and-merge) dummy variable (i.e. diverge=1 and merge=0.)

Comparison between the types of Mainline Toll Plazas using models Log-linear

Data

Data including all types of toll plazas in Florida were used in this approach. A hundred mainline toll plazas, each one has two locations, one before and one after the toll plaza (100*2=200 segments).

Results

For the Log-Linear models analysis, normally, the G^2 goodness-of-fit statistic and p-value are used to determine the rejection or acceptance of the model. Hence, the smaller G^2 is better, but it depends on the degrees of freedom. The larger p-value (>0.05) indicates that the estimated model fits the relationship. The values of the G^2=1.27, P-value=0.5311, and the DF=2 indicated that the model significantly fits the data. So, it can describe the associations between the variables by computing the odds ratios.

Conclusion

The results of this study proved that there is a significant difference between the different designs of the HMTP. The Incident Rate Ratios (IRR) value shows that the risk of crashes at design 2 (D_2) of the HMTP was approximately 19 percent higher than at the design 1 (D_1), given that all other variables are constant. The increased crash risk at D_2 may be explained by the fact that more than 81 percent of the vehicles in Florida are equipped with prepaid toll transponders. Thus, the use of D_2 will cause more than 81 percent of the traffic to diverge and merge before and after the toll plaza.

Another finding is there is an indication that the majority of crashes occurred at diverge and merge areas before and after the HMTP. The IRR value shows that the risk of crashes at diverge areas were approximately 23 percent higher than at the merge areas, given that all other variables are constant.

Moreover, the results indicated significant relationships between the crash frequency and toll plaza types, annual average daily traffic, and driver-age. This means all of these three variables significantly affect the frequency of toll plazas-related crashes.

It was also found that the HMTP and the AETC were associated with less number of crashes than at the traditional mainline toll plaza by 44.7 and 72.6 percent, respectively.
For those agencies that cannot adopt the HMTP and the AETC systems, improving traffic safety at traditional toll plazas should take a priority.

Acknowledgements

The authors wish to thank SAFER-SIM for partially funding this research. SAFER-SIM is a RITA funded UTC Center lead by The University of Iowa. We also thank the Florida Department of Transportation (FDOT) for providing the data that were used in this study, and for funding this research. All opinions and results are solely those of the authors.