BEFORE AND AFTER STUDY: EVALUATING THE SAFETY EFFECTS OF A THRU-U-TURN INTERSECTION

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ABSTRACT

Due to the stochastic nature of accidents/crashes, safety is often misrepresented and misdiagnosed. In addition, statistically significant data required to analyze safety is generally unavailable. This project utilized a Surrogate Safety Assessment Model (SSAM) to predict accidents/crashes as potential conflicts. A Microscopic Traffic Simulation Software known as VISSIM was utilized to simulate a facility known as a Thru-U Turn. The trajectory (.trj) output file from VISSIM was used as the input for SSAM. Using SSAM, potential conflicts were obtained for different scenarios and a Before-and-After study was conducted to analyze the safety of the facility.

PROJECT DESCRIPTION/OBJECTIVE

As the population continues to increase, there is also an increase in the number of drivers on the road and the potential impacts on safety. During the year of 2014, 32,675 fatalities occurred on the US roads with 2,338,000 people suffering from trauma and injuries [6]. To alleviate the traffic safety concerns, one of the techniques that have been implemented over the last few years is the idea of Access Management which is defined as “the systematic control of the location, spacing, design, and operation of driveways, median openings, interchanges, and street connections to roadways” [4]. One access management technique in particular eliminates problems associated with left-turns and crossing movements by relocating the direct left-turns to a downstream U-turn bay. From an operational standpoint, Wang et al. [9] and Carter et al. [1] determined that U-Turn’s adversely affect the delay and saturation of an intersection and decrease its capacity. However, Liu et al. [5] conducted field measurements at 40 sites and concluded that right-turns followed by a U-turn at a downstream median does not increase delay and travel time. Similarly, Stamatiadis et al. [8] and Pirdavani et al. [7] employed simulation software to predict travel time based on geometry, volume, and percentage of left-turns. Simulation results for different scenarios run concluded that the median U-Turn would be a good alternative to improve system travel time over conventional designs. On the safety side, Carter et al. [1] examined U-turn crash history of 78 signalized intersections and found that 65 of the 78 sites did not have any collisions involving U-turns in the three-year study period. Researchers concluded that U-turns do not have a large negative safety effect on signalized intersections. Another study [3] also noted that U-turns promote a safer intersection by reducing the number of conflict points. Another study drew similar inference by observing that vehicles making right turns followed by U-Turns at a median opening will generate 47% fewer conflicts than those making direct left turns from a driveway. This study further noted that the presence of U-turn will reduce the crash rate by 26% and the injury/fatality crash rate by 32%. The objective of this paper will focus on median U-turns (analyzing facilities called Thru-U turns) and evaluating the true underlying safety effects of the implementation of these U-turns by doing a before and after study. The true safety effects of the facility analyzed were originally proposed to be measured by using the Empirical Bayes Method approach, which combines the strengths of a before and after study that uses specific case control techniques with regression methods for estimating the safety. However, due to the uncertain nature of traffic accidents and the availability of data for the particular type of intersection analyzed, a Surrogate Safety approach was conducted. The traffic conflict data was obtained using the Surrogate Safety Assessment (SSA) model by supplying it inputs from traffic simulation software called "VISSIM". Once the data was obtained from the SSA model, a naïve before and after study was conducted.

DATA COLLECTION

The safety data for this type of facility is not readily available and that is why a Surrogate Safety Assessment Model was used to estimate crashes for the facility. In order to develop and calibrate the model for existing and future conditions, data including geometry, volumes, signal timing, travel times, etc. were obtained from Utah's Department of Transportation and from Avenue Consultants. A model was built for different scenarios including Before and After conditions for Existing/Future PM and Mid-Day periods for a total of 8 scenarios. The simulation was run for 1 hour interval and the data collected by running the simulations were outputted in a trajectory file (.trj). Once again, since 5 runs were simulated through VISSIM, 5 different trajectory files were analyzed and recorded by SSAM. Each analysis scenario resulted in a summary table, and results for all 5 runs were then broken down into lane-changing, rear-end and crossing conflicts (refer Table 1).

Table 1. Average Crash Conflict Data

PM	**Before**	**After**
Crossing	158	119
RearEnd	796	831
Lane Change	224	416
Total	1179	1366
MID	**Before**	**After**
Crossing	131	112
RearEnd	396	705
Lane Change	193	435
Total	720	1253
2030 PM	**Before**	**After**
Crossing	810	271
RearEnd	1283	1259
Lane Change	363	561
Total	2456	2091
2030 MID	**Before**	**After**
Crossing	584	309

RearEnd	905	1048
Lane Change	291	581
Total	1780	1938

It must be noted that the crash conflict data have been filtered in order to alleviate erroneous outputs. In particular, SSAM did not recognize a change in elevation at the freeway interchange. Due to this, the freeway and major arterial were perceived at the same elevation and SSAM generated conflicts for that stretch. As a solution, the links on the freeway and the interchange were filtered out and were not included as part of the study.

METHODOLOGY

Site Selection

Selection of the sites was determined based on the intersection facility analyzed (Thru-U turn). Although there have been many studies in regards to median U-turns, this particular intersection known as a Thru-U has not been analyzed. In order to demonstrate the abilities to evaluate the safety of a new type of intersection, a Thru-U Turn facility was chosen as the intersection of choice. The study area encompasses major commercial developments on all four corners of the concerned intersection.

Simulation vs. Historical Data

Since the facility of a Thru-U Turn is fairly new, data in regards to accidents has not been collected yet. Furthermore, this data, even if readily available, could represent erroneous information. The problem in utilizing historical data is the nature of accidents themselves. Accidents are a random and stochastic number that changes every day. There are several factors that affect safety and crashes including human emotions, traffic volumes, weather conditions, traffic regulations, and other things. In order to use this data, statistically significant crashes must be obtained to properly analyze safety. A more feasible alternative of utilizing simulation was presented by SSA model which uses crash frequency to estimate where a potential accident might occur. Although this method has not been proven yet, it is a great alternative to the normal historical data approach.

Calibration and Validation Utilizing VISSIM

In order to represent the most accurate results, VISSIM simulations must be altered to replicate the existing conditions. As described previously, VISSIM utilizes models that consider the behavior of the vehicles including the car-following model and lane-changing model.

Simulation Run Parameters

After the model is setup and adjusted, in order to run the simulation, there are several parameters that affect the way the simulation runs. For this particular project, the simulation period was set to 4500 seconds (1 hour and 15 minutes). This is because the model requires a period of time to warm up and populate. In order to simulate a desired one hour interval, an additional 15 minutes was added to resolve this issue. Another key criterion is the Simulation Resolution which displays a snapshot of the vehicle. It behaves like a camera and gives the location of the vehicle for a higher simulation resolution. The parameter takes input of 1-10 seconds/simulation second. For this particular project, a simulation resolution of 5 was utilized. There is no particular reason as to why 5 was chosen. Another key parameter that was considered is the Random Seed. VISSIM itself is stochastic simulation software, and these random seeds allow for a slightly different scenario. Each random seed can be an alternative scenario. In order to account for this these random scenarios, 5 seeds from 1 to 5 were chosen with an interval of 1. Each simulation seed and run outputs a different trajectory file. 5 runs were arbitrarily chosen due to the large file size output by these trajectory files.

Conflicts Evaluated

This project analyzed three types of conflicts in congruence with the outputs displayed by the SSAM. The three types of conflicts are crossing, rear-end, and lane-changing. SSAM utilizes complex algorithms to identify each type of conflict based on the trajectory (.trj) file provided by the simulation software. In addition to the conflicts defined, SSAM defines several time dependent parameters that filter the conflicts. For different parameters, different crash frequency is presented.

Safety Equations

Once the SSAM is run, crash frequencies were collected from the output and safety was then analyzed by following the traditional before-after study procedure. The first task consists of predicting the expected number ($\hat{\pi}$), an estimate of π, of target crashes for a specific entity (i.e., intersection, segment, etc.) or series of entities in the "after" period had the safety treatment not been implemented. The second task consists of estimating the number of target crashes ($\hat{\lambda}$) for the specific entity in the "after" period. Here, the term "after" means the time period after the implementation of a treatment; correspondingly, the term "before" refers to the time before the implementation of this treatment"

According to Hauer et al. [2], the following 4 steps can be used to estimate safety.

1. estimate λ(j) and π(j)
2. estimate $Var\{\hat{\lambda}(j)\}$ and $Var\{\hat{\pi}(j)\}$
3. estimate $\hat{\delta}$, where $\hat{\delta} = \hat{\pi} - \hat{\lambda}$ (reduction or increase in target crashes) (1)
4. estimate $\hat{\theta} = \frac{\left[\frac{\hat{\lambda}}{\hat{\pi}}\right]}{\left[1+\frac{\mathrm{Var}\{\hat{\pi}\}}{\hat{\pi}^2}\right]}$ (2)

When θ<1, the treatment is effective; when θ>1 it is harmful to safety.

and $Var(\hat{\theta}) = \hat{\theta}^2 \left\{\left[\frac{Var(\lambda)}{\lambda^2}\right] + \left[\frac{Var(\pi)}{\pi^2}\right]\right\} / [1 + Var(\pi)/\pi^2]^2$ (3)

RESULTS

At first glance, a review of crash data (Table 1) reveals that Thru-U Turns increase the total number of potential conflicts except for the 2030 PM Conditions. Simple comparisons also reveal that overall, crossing maneuver accidents tend to decrease while rear end and lane changing maneuver accidents tend to increase. Theoretically, these numbers seem logical due to the restriction of left-turns and the addition of right-turns followed by U-turns. In case of the 2030 PM conditions, rear end for the after period is lower than the before period. These numbers could conveniently have been higher through different random seeds or even re-running the same 5 random seeds used to analyze the intersection. As such, the data remains accurate and consistent. The biggest discrepancy in this scenario is that the overall after period accidents is lower than the before period. Taking a closer look, it is clear that the cause of this occurrence is due to the larger difference between crossing maneuvers. One could make an observation that the higher the volume is, the more crossing maneuvers there will be for the before period and the lower crossing maneuvers there will be for the after period. In other words, the high the volume, the greater the difference will be between crossing maneuver for the before and after period and if the difference is greater enough, it could potentially make the overall intersection safer. The same case could have also occurred for the 2030 MID conditions. In order to accurately represent safety, the 4 step model described was used to analyze the intersection (See Table 2).

Table 2. Effective Safety Measures

PM	π	λ	$\hat{\delta}$	$\hat{\theta}$	**Std θ**
Crossing	158	119	39	0.75	0.090
RearEnd	796	831	-35	1.04	0.052
Lane Change	224	416	-192	1.85	0.152
Filtered	1179	1366	-187	1.16	0.046
MID	π	λ	$\hat{\delta}$	$\hat{\theta}$	**Std θ**
Crossing	131	112	19	0.85	0.109
RearEnd	396	705	-309	1.78	0.111
Lane Change	193	435	-242	2.24	0.193
Filtered	720	1253	-533	1.74	0.081
2030 PM	π	λ	$\hat{\delta}$	$\hat{\theta}$	**Std θ**
Crossing	810	271	539	0.33	0.023
RearEnd	1283	1259	24	0.98	0.039
Lane Change	363	561	-198	1.54	0.104
Filtered	2456	2091	364	0.85	0.025
2030 MID	π	λ	$\hat{\delta}$	$\hat{\theta}$	**Std θ**
Crossing	584	309	275	0.53	0.037
RearEnd	905	1048	-143	1.16	0.052
Lane Change	291	581	-290	1.99	0.142
Filtered	1780	1938	-158	1.09	0.036

As mentioned before, the same conclusions can be made from $\hat{\delta}$. Furthermore, “index of effectiveness” represents effectiveness of the treatment. A review of Table 2 presents that Thru-U Turns, as a whole, are harmful to safety with values over 1. More specifically, the same trends can be found as per the increase/decrease of accidents. While the treatment is effective on the crossing maneuvers, they are also harmful for the rear end and lane changing maneuvers. It is uncertain whether or not Thru-U Turns are an effective safety alternative. While the overall trend indicates that Thru-U Turns are not safe, the peak condition suggests the opposite. It can be confidently said that overall, Thru-U Turns decrease the potential number of conflicts/accidents on Crossing Maneuvers and likewise, increase the number of conflicts points/accidents on Rear End and Lane Changing Accidents.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the safety of Thru-U-Turns can be directly related to the amount of traffic volume. In particular, the larger the volume, the larger the potential for the "crossing" maneuver to offset the overall intersection safety. In other words, Thru-U-Turns tend to be harmful for low volume scenarios and become safer as the volume increases. It continues to be safe until a limit where the "crossing" maneuvers difference between the before and the after offset the addition of the other two maneuvers (rear end and lane change) and makes the intersection safe. It is unclear at which point the intersection transitions from unsafe to safe but it conclusive that it can be attributed to the increasing vehicle volume and the overall difference in "crossing" maneuvers. Further analyses must be done to determine whether or not Thru-U-Turns are safe or unsafe. This project only dealt with analyzing safety based on conflict type and must be tested to include conflict severity. Furthermore, VISSIM simulation parameters must be tested and explored. In addition, SSAM must be evaluated for potential bugs/deficiencies (i.e. elevation). Simulation and SSAM provides a great alternative to analyzing the potential safety effects of a facility but due to the novelty of such software (especially SSAM), it is unclear whether this is a good or method or not.

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