TOWARDS SUSTAINABLE ROUNDABOUT: AN EVALUATION OF DRIVER BEHAVIOR, EMISSION AND SAFTEY

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Abstract: Roundabouts have been gaining acceptance by city planners and traffic engineers alike. Due to this rise in use, there has been a need to better understand the characteristics roundabouts have and how they affect the performance of transportation networks. Sustainability-related advantages of roundabouts are of particular interest. Field data were collected for the purpose of determining the critical gap at a double single-lane roundabout and whether that value is substantially different than other types of intersections like stop-controlled intersections. Critical gap values are used in micro-simulation software and the more accurate the input data are the more accurate the model behaves compared to reality. Micro-simulation software was used to develop models for two roundabouts, a single lane roundabout and a double single-lane roundabout. The single-lane roundabout was previously a signalized intersection and the double single-lane roundabout used to be two stop-controlled intersections. Models of both the current conditions and the previous conditions of these two locations were developed for both the morning and evening peak periods of demand. This research showed that the critical gap at a roundabout is significantly different than the default values used in micro-simulation. The stop sign controlled intersections, which were the before condition of the double roundabout produced higher emissions than the double roundabout. The signalized intersection, which was the before condition for the single-lane roundabout, produced considerably fewer emissions than the single-lane roundabout. SSAM was shown to be a reliable tool for estimating the total number, type, and location of conflicts that occur at both locations.

Key words: Roundabout, transportation network, micro simulation, controlled intersections, high emission level

I INTRODUCTION

Innovation is necessary in order for society to move forward. Striving for progression has led to serious global consequences. The footprint left by mankind is still constantly expanding but the difference is that people are aware and make efforts to grow in such ways that leave the Earth intact for future generations. This type of growth has been christened sustainable, a relatively new field of study that is gaining acceptance and respect throughout the world.

Particularly, in the field of transportation engineering this term has become the new buzz word. Large amounts of government funding are being handed out for projects focused on sustainability, meaning thousands of studies are being conducted in order to discover new innovative ways to design, construct, operate, and manage transportation systems in a more efficient, equitable, and environmentally friendly manner.

Due to roundabout rise in use, there has also been a rise in the number of studies performed on roundabouts so that they can be better understood and implemented. More recently, these studies have focused on whether roundabouts have sustainability-related advantages, such as improved air quality due to decreased emissions or improved safety which leads to economic savings, when compared with other types of intersections.

II LITERATURE REVIEW

Gap availability delves into examining all the gaps that are present at an intersection. This metric can help explain why drivers choose to accept particular gaps over others. Areas with few large gaps would be expected to have gap acceptance values that are relatively low. Baranowski Polus et al. (2013) conducted a study on gap availability at two single-lane roundabouts in Maryland. The study concluded that all drivers will always accept gaps of 8.2 seconds or greater. Gaps of 8.2 seconds and larger should be excluded from the data set when determining the critical gap to ensure the results are not skewed. The study also examined gap acceptance. The critical gaps at the two site locations they tested were 3.85 and 3.91 seconds. According to the authors these values are substantially lower than the values recommended by the 2000 Highway Capacity Manual (HCM 2000). Similarly, the follow up times, or headways, recorded were 1.9 and 2.1 seconds. Follow up times are the time distance between two consecutive vehicles measured from the front of the leading vehicle to the front of the following vehicle. Again the authors state these values are considerably lower than the HCM 2000 recommended values of 2.6 and 3.1 seconds respectively.

Gap availability at seven single-lane roundabouts in California was assessed by Xu and Tian (2014). The average gap at the test sites was 4.8 seconds with a standard deviation of 1.1 seconds. Gap availability at three two-lane roundabouts was also assessed in this study and the average gap was found to be 4.7 seconds for vehicles entering from the left lane and 4.4 seconds for those entering from the right lane. The critical gap at the test sites was also determined. At single-lane roundabouts the critical gap ranged from 4.5 to 5.3 seconds and at two-lane roundabouts from 4.0 to 5.1 seconds.

Abrams et al. (2015) evaluated the roundabout located on the campus of the University of Massachusetts Amherst for both spatial and temporal gaps accepted by drivers. Spatial gaps represent the physical distance and temporal gaps the time distance between two subsequent vehicles. The results showed that the average accepted spatial gap was 42 feet and the average temporal gap was 2.2 seconds. These values are much smaller than those determined from previous studies, which stated the temporal gaps were closer to 4 seconds. Vasconcelos et al. (2016) determined that critical gaps at roundabouts in Portugal vary between 3.2 and 3.7 seconds.

III METHODOLOGY

1. Study Design

The study design is composed of the research objectives, research tasks, and research contributions.

2. Literature Review

A comprehensive literature review was conducted. This provided an in-depth understanding of issues related to driver behavior, safety, and air pollutant emissions at roundabouts. It also ensured that all the strengths and weaknesses of the previous research studies were identified..

3. Critical Gap Field Study

Gap availability, acceptance, and queuing data were collected from 7:30 AM to 8:30 AM (i.e., the morning peak period) and from 4:30 PM to 5:30 PM (i.e., the evening peak period) at a double roundabout .The purpose of collecting gap availability and acceptance data were to determine the critical gap at the intersection.

The data were collected with the use of a program, Gap Acceptance Processing System (GAPS), developed at UMass and adjusted specifically for this project using Microsoft Access. Only one person is required to operate this program in the field and it does not require anything more than a typical laptop to run. Proper procedures for collecting data were explained and followed by all persons involved in the data collection process. The "Gap Acceptance Study details the steps involved in completing a gap acceptance study. Most of the data analysis was automated using the GAPS program in Microsoft Access and Microsoft Excel. After the vehicle data were entered into the GAPS program a basic analysis was run which outputs data in a form that can be imported to a spreadsheet in Microsoft Excel.

4. Calibration and Validation SSAM Models

In order to perform more extensive tests for assessing emission levels at roundabouts micro-simulation was used. Four different models were developed .The first represents the before conditions of the pre-timed signalized intersection. The second represents the before conditions of the two stop-controlled intersections that are now a double single-lane roundabout The other two models consist of the two after conditions of the locations .The models were calibrated and validated for the after conditions using data collected through cameras at both locations.

5. Before and After Comparison of Emissions through Simulation

The fully calibrated and validated models were used to estimate vehicle emissions including NOx and CO. Multiple simulation runs were processed to account for in the inputparameters and their outputs were used to obtain average emission estimates. A detailed comparison of the before and after conditions was conducted to assess whether roundabouts do in fact decrease vehicle emissions compared to signalized and stop-controlled intersections.

6. SSAM Analysis

SSAM was used through simulation to estimate conflicts for the single-lane roundabout and double single-lane roundabout mentioned above. SSAM allows for the type of conflicts to be filtered by conflict type. Rear-end, lane change, and crossing conflicts are the three types of conflicts recorded by SSAM. The severity of these conflicts is represented by the value of time-to-collision (TTC) registered by SSAM. TTC values range from 1.5 seconds to 0 seconds decreasing by half second intervals. A TTC value of 0 seconds indicates a collision where a TTC value of 1.5 seconds indicates driver following behavior that is dangerous. The location of the conflicts on the network is another aspect of the SSAM software that is helpful in developing countermeasures. The SSAM results were compared to the safety analysis conducted on the video collected at those two locations.

7. Comparison of Field and Simulation Safety Data

In addition to calibrating and validating the micro-simulation models, video recorded at each of the site locations was used to compare the model results from SSAM to the real-world results. Due to the limitations of only having video data the severity of video conflicts were not estimated. Only number of conflicts, type of conflict, and location of the conflict were determined from the video. This comparison was performed for investigating the reliability of SSAM to estimate conflicts at both a single-lane roundabout and a double single-lane roundabout.

IV RESULTS

The field study performed to evaluate the impact of pedestrian volumes on vehicular emissions, in particular, carbon dioxide (CO_2) emissions. The models can estimate CO_2, CO, fuel consumption, acceleration and deceleration rates, speed, and elevation. A highCO_2 emissions event is defined as any instant when CO_2 emission levels are higher than 6 g/s. Using recordings data, a comparison was made to determine if those high level of CO_2 emissions were experienced when pedestrians were present at crosswalks, which made vehicles slow down or stop. The higher the number of stops and acceleration/deceleration cycles a vehicle goes through, the higher the level of emission output from the vehicle. Comparisons of speed profiles during different events, such as yielding to a pedestrian at the roundabout, yielding to a vehicle at the roundabout, being in a queue at the roundabout, or yielding to multiple pedestrians were also made.

Subjects were scheduled based on convenience so not all subjects were run during the same time of day or day of the week. Runs were constrained to weekdays from about 8:00 AM to 5:00 PM in order to ensure that runs were conducted during times pedestrians are most likely to be walking around campus. The results of the field study for all 5 loops, for each subject broken up into 10 runs one for the eastbound direction of every the loop and one for the westbound direction of every loop.

V CONCLUSION

Overall, it appears that SSAM is an adequate tool for estimating conflicts at single-lane roundabout and double single-lane roundabouts as long as the entry volumes are high enough to cause a considerable number of conflicts per hour. Only during the morning peak period at the Shivtirth garden Corner double single-lane roundabout the SSAM estimated a number of conflicts that did not match the conflicts observed from the data. The location of the conflicts estimated by SSAM at both roundabouts during both peak periods had a strong correlation with the location of the conflicts obtained from the data. The most common location of conflicts was on the entering and exiting legs. SSAM and the field data had a similar percent split between rear-end conflicts and lane change conflicts at each roundabout during both peak period. The percent split was different for each model but there was a trend that more rear-ends conflicts occurred than lane change conflicts.

The emission data did not produce any pattern in relation to high emission events and number of pedestrians at roundabouts. Most of the high emission events either happened for a different reason than pedestrians or did not occur at the roundabout. There was also no correlation between the total number of stops and the average or total CO_2 produced during a run, which is contrary to what the literature tells us. In the future more subjects need to be used to get a larger database from which to make conclusions.

It is suggested that SSAM is to estimate conflicts at a variety of roundabouts with various characteristics to ensure that SSAM continues to prove to be an accurate tool for estimating the number, type, and location of conflicts at roundabouts. Proving that SSAM is an accurate tool for estimating conflicts at roundabouts has implications for evaluating alternative designs developed for future projects before implementing those designs in the field.

It would be prudent to evaluate more roundabouts with various geometric designs, entry volumes, and turning ratios to further understand how the critical gap changes when intersections are converted to double single-lane roundabouts. This would help improve micro-simulation models that are developed as alternative designs for future projects.

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