A Conceptual Approach for Using the UCF Driving Simulator as a Test Bed for High Risk Locations

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Abstract

The main objective of this paper is to illustrate the use of the UCF Driving Simulator as a test bed for high-risk locations such as signalized intersections and toll plazas. The Alafaya (SR434) – Colonial (SR50) signalized intersection in Orange County, Florida, is used to validate the simulator. The SR 434 - SR 50 intersection is four-leg 6×5 signalized intersection, and has two left turn lanes and one right turn lane for every approach. Both safety and traffic measures are being used in our effort to validate the simulator and therefore prove its usability as a test bed. Safety will involve identifying the potential safety problems from the crash reports, then we will observe whether subjects will face the same problems in the simulator, thus validating it. The traffic measure would be the speed distribution. Speed measures in the field will be compared with the driving speeds of the subjects crossing the intersection in the simulator, again for validating it. Multiple scenarios is being developed covering the different safety problems and approaches to the intersection. Using the Florida Department of Transportation Crash Analysis Reporting (CAR) System, the crash reports at this intersection for the years 1999 to 2002 were obtained and analyzed. Of the 164 crashes that happened during the 4 years at the intersection, 95 have been rear-end. It has been found that most of the rear-end crashes took place in the right–turn lanes of SR 434. The new approach here is the use of crash history to identify the high risk locations and type of collisions at the intersection, and then observe the "near misses" in the simulation. If both coincide, this could be one of the validation criteria that could be used. A between-subjects 3X2 (3 age groups and 2 genders) factorial experimental design has been modeled. Sixty subjects will drive the simulator, running through 11 scenarios, mainly the right turn lanes on SR434 in both the directions, when the signal is green/red/amber for traffic on SR50 (for traffic conflict validation), the through lanes on SR434 when the signal is green (for speed validation), and the through lane on SR50 when the phasing changes from Green to Amber. Measurements of Speed, Deceleration rate, the position of stop and the steering performance, will be collected. Also the effect of gender and age will be assessed.

Introduction

For a driving simulator to be a meaningful endeavour, it is essential that the correspondence between a real and simulated environment is sufficiently good. It is of special importance that road-user behaviour is sufficiently similar in both situations; i.e., it is essential that the driving simulator is sufficiently valid with respect to driving behaviour. The UCF driving simulator is a high fidelity state-of the art driving simulator. The main aim of this project is to use the UCF Driving Simulator as a Test-bed for high-risk locations. A signalized intersection and toll plaza are definitely two such high-risk locations. Test-bed as such means being able to drive a high-risk location or a location that is considered for modifications or has a particular problem, in the driving simulator. The UCF Driving Simulator is being used for this purpose. Previous studies at the UCF Driving Simulator demonstrated that driving simulator offers driver sufficient visibility of the surroundings to recognize appropriate stimuli, especially moving objects and react accordingly. The data collected from the driving simulator can be applied to analyze the safety of existing roads and intersections. Using the driving simulator as a test-bed, as defined above, to identify such critical locations is a new and challenging task. There are studies that mention about using the driving simulator at an intersection, none of them look at trying to use the driving simulator as a test-bed. Considering the fact that the right turning lanes at the SR 4343-SR 50 intersection pose a safety problem, the scenarios most of the scenarios have been designed to test this issue. To do this, the scenarios require the subjects to drive through the intersection when the phase is green on the Alafaya South bound and Colonial Drive West Bound. The speed distribution would be comparable with that of the real world speed data. The effect of age and gender in the driver performance will also be analyzed. A preliminary pilot study would be done to justify the scenarios. Data would be collected and analyzed. The results would then be incorporated in designing the final scenarios.

Background

Blaauw (1982) proposed two levels of validity: Physical validity and Behavioral Validity. The physical validity corresponds to the simulator's components, layout, and dynamics with its real world counterpart. The behavioral validity is measured using two types of validity- absolute validity (when the numerical values between the two systems are the same), relative validity (when differences found between experimental conditions are in the same direction, and have a similar or identical magnitude on both systems). According to Tornros (1998), for a driving simulator to be useful as a research tool it is necessary that the relative validity is satisfactory, i.e. the same, or at least similar, effects are obtained in both situations. Absolute validity is not a necessary requirement, since research questions uniquely deal with matters relating to effects of various independent variables, with experiments investigating the difference between the field measurements and the simulated.

Speed and Safety Studies

The main aim of this experiment is to validate the driving simulator in two main aspects- Safety and Speed. To achieve this, a critical location was chosen – a signalized intersection. The Alafaya Trail (SR 434) – East Colonial Drive (SR 50) intersection and located in Orange County, Florida were chosen at the test spot because of its high crash rate history. The SR 434 - SR 50 intersection is four-leg 6×5 signalized intersection, and has two left turn lanes and one right turn lane for every approach. Both safety and traffic measures are being used in our effort to validate the simulator and therefore prove its usability as a test bed. Using the Florida Department of Transportation Crash Analysis Reporting (CAR) System, the crash reports at this intersection for the years 1999 to 2002 were obtained and analyzed. Of the 164 crashes that happened during the 4 years at the intersection, 95 have been rear-end. It has been found that most of the rear-end crashes took place in the right–turn lanes of SR 434. With this in mind, the objective for designing the scenarios to be tested was developed. Multiple scenarios with subjects driving through the intersection during various phases and various lanes were designed.

To validate the driving simulator in the speed aspect, various field measurements were carried out at the intersection. Speeds at various locations on different approaches were measured at the field. The speed profiles of the measured values are expected to be similar to that of the speeds recorded at the similar locations in the driving simulator. If this happens, then the simulator could be said to be validated, as per the study mentioned above.

Speed Studies

From the field, the speed of the vehicles entering the intersection during a green phase was recorded at 6 different positions. On an average, the speed of 100 vehicles at six different locations between 11:00 AM and 1:00 pm (Off peak period on Thursday) was measured using a speed gun on Alafaya Trail Southbound and Colonial Drive Westbound approaches. Speeds were measured only for those vehicles that were travelling straight on either Alafaya Southbound or Colonial Westbound. On both the approaches, three distinct points were chosen for measuring the speeds- approximately 200ft upstream of the intersection, approximately 100ft upstream of the intersection and approximately 100ft downstream of the intersection. On Alafaya Trail, the mean speed was found be around 43 MPH. The posted speed limit on the approach is 45 MPH. Nearly 41% of the vehicles travelled at speeds around 40MPH. And on Colonial drive, nearly 72% of the vehicles travelled between speeds 40MPH and 50 MPH while the posted speed limit was 50MPH. Figure 1 below elucidates the mean speed on vehicles travelling on Colonial Drive westbound through lanes.

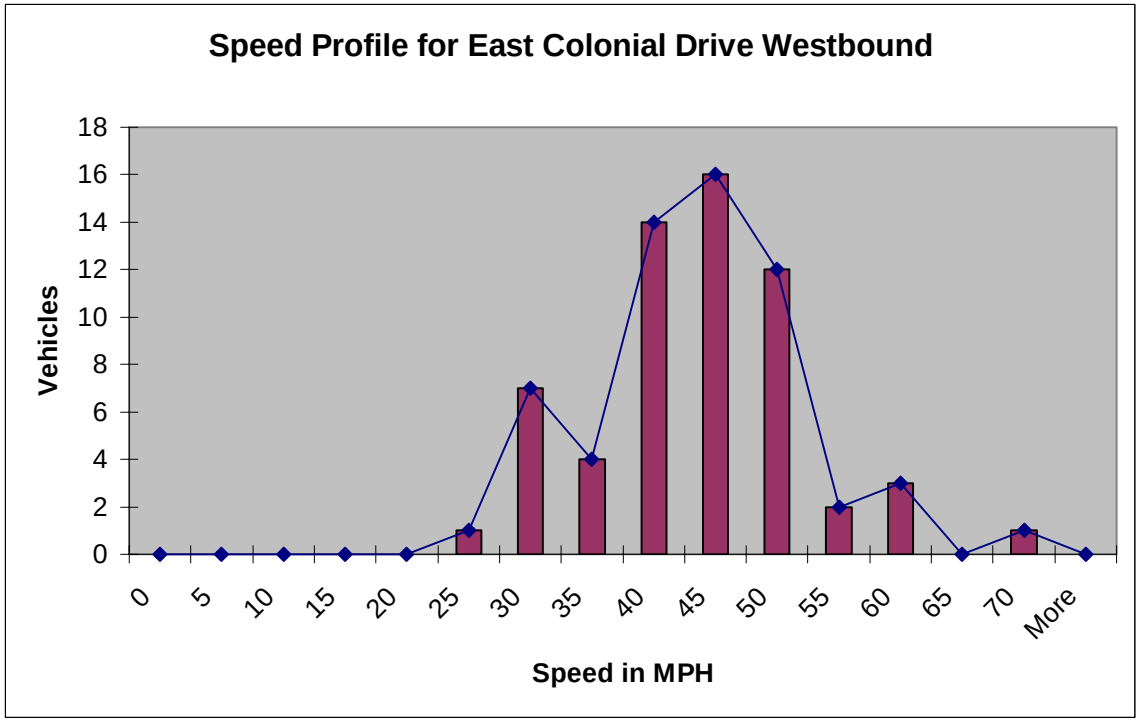

Figure 1: Frequency Histogram for Speed Distribution on East Colonial Drive Westbound through lanes. (Off Peak Period)

The measured mean speeds of the vehicles could be compared with that of the speeds in the driving simulator. The speed profiles of the two might be compared. The simulator is said to be validated if the profiles are similar, if not same. Figure 2 represents the speed profile on Alafaya Trail Southbound at three different locations as mentioned above.

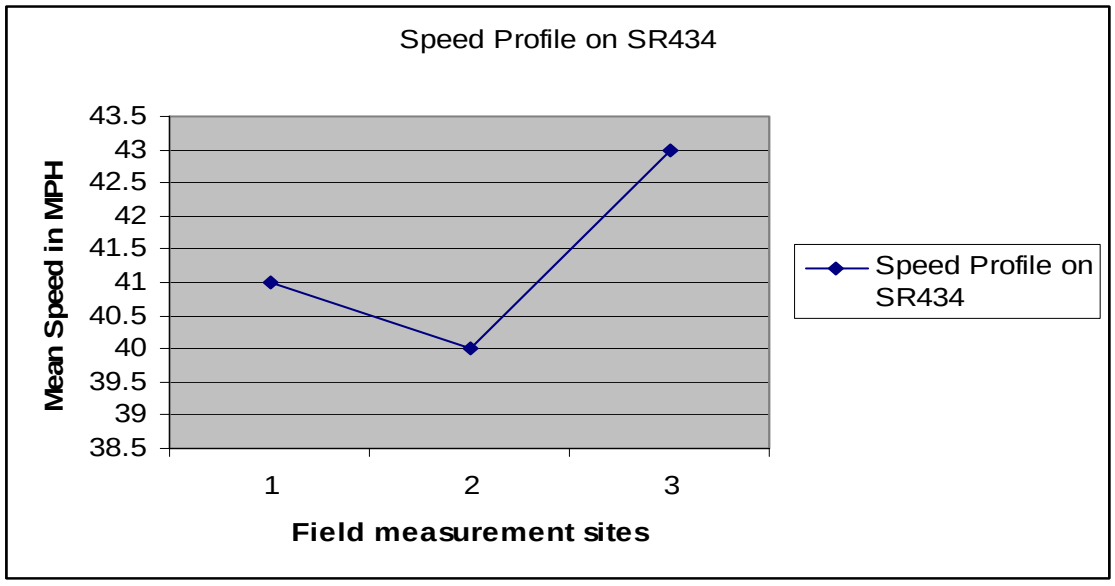

Figure 2: Speed Profile on Alafaya Trail at the three test sites

Experimental Design

The measures or the dependent variables would be Speed, Deceleration rate, the position of stop and the steering performance. The experimental design used here is a simple between-subjects factorial design. The two independent variables (factors) are age group and gender of the subjects. There are three levels for age group (Very Young, Young and Middle aged) and two levels for gender (Male and Female). The experimental setup results in a 5 X 2 between-subjects factorial design. The age groups have been classified as Very Young (15 to 19), Young (20 to 24) and Middle aged (25 to 64). This classification has been done on the basis of a previous study by Abdel-Aty et al. (1998). Since the middle age group is a large set, based on the crash analysis done using the crash reports, the Middle aged group has been further reduced to 4 groups- Younger Middle aged (25 to 34), Middle Middle-aged (35 to 44), Older middle-aged(45 to 54) and Very old Middle-aged (55 to 64). Since no crashes were found in the very old middle-aged group, it has been discarded. Hence, the five groups of interest are Very Young (15 to 19), Young (20 to 24), Younger Middle-aged (25 to 34), Middle Middle-aged (35 to 44) and older middle-aged (45 to 54). This age categorization follows the actual driver population using the intersection of interest. The approach type would also play an integral part in the results; this has been incorporated in the different scenarios that have been designed for the experiment.

Scenarios

Based on the discussion regarding the safety and speed validation, a total of nine scenarios will be tested on the subjects. The eight scenarios include the right turn on Alafaya Northbound, the through lanes on colonial drive Eastbound and Alafaya Northbound, for the safety evaluation - the Alafaya Southbound through lane and Colonial Westbound through lane for the speed validation. In order to make the crash rate at the Alafaya Trail Northbound right turn lane substantial, it will be compared to the Colonial Drive East bound right turn lane where the crashes have not been predominant. Similarly, the crashes on Colonial Drive Eastbound through lanes when compared to the crashes on Alafaya trail Northbound through lane are higher, which would make a better pair for comparison and help us in obtaining better results. The following would be scenarios that we intend to test. A three minute practice session will be given to all the subjects to get familiarized with the simulator. They will be told to drive a generic network built within the system. For the Right-turn lane scenarios, the simulator will act as both the “striking” vehicle and also the “struck” vehicle, depending on the scenarios.

1. Alafaya Northbound Right Turn

Under this case, looking at the possible causes for crashes from the ‘Alafaya-Colonial Crash Analysis’, it was concluded that the following two cases need to be tested:

A. Right turn onto Colonial Drive East bound when the phase is red for Alafaya Northbound through lanes with the driving simulator as the lead vehicle. Figure 3 gives an idea about the scenario.

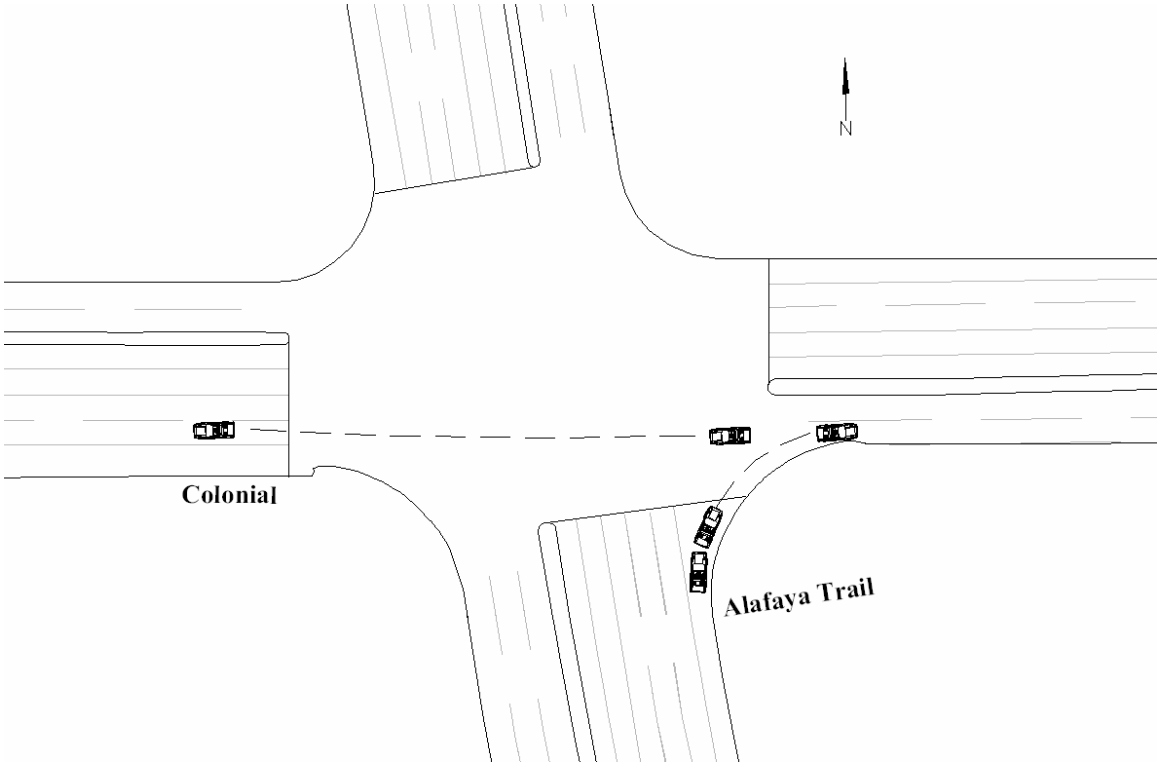

Figure 3: Vehicle turning right onto Colonial Drive from Alafaya Trail Northbound

B. Right turn onto Colonial Drive East bound when the phase is red for Alafaya Norththbound lanes with the simulator as the following vehicle. From scenario A, the lead vehicle (i.e. simulator) deceleration rate can be obtained and used as the deceleration rate of the lead vehicle in this scenario. This would make the scenario more realistic and also check for potential crash rate as the lead or following vehicle.

2. Colonial Drive East bound Right Turn

As in the previous case, for being able to depict the possible crashes on Alafaya Northbound right turn better and hence to be able to justify that simulator is a test bed, it is necessary that the following two cases be tested:

C. Right turn onto Alafaya South bound when the phase is red for Colonial Drive East bound through lanes with the simulator as the lead vehicle.
D. Right turn onto Alafaya South bound when the phase is red for Colonial Drive east bound through lanes with the simulator as the following vehicle.

3. Colonial Drive Eastbound through Lanes

Here, since the crashes on the both directions are almost similar, we can consider one direction for designing the scenario. Also, as mentioned above, a scenario testing the crashes on through lane on Alafaya trail Northbound would be included.

E. Colonial Drive East bound when the phase is changing from green to amber to red.
F. Alafaya Trail North bound when the phase is changing from green to amber to red.

4. Alafaya Trail through Lane
   G. In this case, used for speed validation, we will want the subjects to drive through the Alafaya Trail South bound when the phase is green for the through lanes.

5. Colonial Drive Westbound through Lane
   H. The subjects will be told to drive through Colonial Drive Westbound when the phase is green for through lanes. This again would be used for speed validation.

The following scenarios would be used to check if there would be any change in the driver reaction, when there are any changes made to the current intersection. Considering the right turn lane at Alafaya North Bound, the two scenarios designed are

   I. Shifting the Stop Bar – The Stop Bar at the intersection on the Alafaya Northbound would be shifted further, depending on the Stopping Sight Distance of the Vehicles approaching from East Colonial Drive eastbound lane. The subjects would be asked to make a right turn on to East Colonial Drive eastbound lane, after the change in the stop bar is made. The data observed in the scenario could be compared to that of the data observed in Scenario A. This will enable us to strengthen our point that the Driving Simulator could be used as a Test Bed.

Subject Recruitment

Having all the subjects run all the ten scenarios might lead to generation of noise factors like bias, fatigue and also the familiarity with the system might enable the subjects to perform the last scenario better than the rest. Keeping this in mind, the between-subjects design has been used. Also, in general, a fully between-subjects design will always be the most straightforward to analyze. We will also randomize the sequence of scenarios. A minimum of 60 subjects would be used to test the scenarios. Hence, 6 groups, with 10 subjects, a total of 60 subjects. The sequence of scenarios would be randomized for each subject. Table 1 depicts the 6 groups and the scenarios.

Table 1: Different groups and the corresponding runs to be made

GROUPS	SCENARIOS
I	A C E F G H I
II	A D E F G H I
III	B C E F G H I
IV	B D E F G H I
V	A C E F G H I
VI	BD E F G H I

Conclusions

The main conclusion in this paper is that we have illustrated the use of a combination of safety and traffic factors to validate a driving simulator. The new idea is the use of crash history to identify the high risk locations and type of collisions at the intersection, and then observe the crashes or "near misses" in the simulation, based on steering, vehicle path, deceleration rates, braking and speed profile. If safety problems and types coincide, then safety could be one of the validation criteria that could be used. Speed distributions at the different approached during the green phase would also be compared in the field with the simulator for validation.

For the Alafaya right-turn scenarios, it is expected that the deceleration rate, steering performance and the position of stop of the vehicle during scenarios A and C vary considerably with those of B and D respectively. The crash analysis at the intersection also points to the difference in the crash rates for the above mentioned scenarios. It is also expected that there is considerable difference in the dependent variables between the Alafaya Northbound and Colonial eastbound approaches. In the case of Colonial Drive Eastbound through lane, the potential for a red light running during the change in the phase would be recorded. This would be compared with that of the scenario testing the potential crash rate on Alafaya Northbound lane. Since the speed limits, minimum green time, maximum green time and the amber phase time is similar for both the approaches, it is expected that there are higher number of near misses or potential crashes on Colonial because of lesser number of lanes. There are 2 Colonial eastbound through lanes while, there are 3 through lanes for vehicles on Alafaya Northbound, which gives the drivers on Alafaya ample space to shift lanes in case of sudden stop.

For the speed validation, the speed profiles of the Alafaya Southbound vehicles and Colonial Drive Westbound vehicles from the field would be compared with that of the speed profiles of the subjects driving the simulator through the same lane at similar conditions. This procedure for evaluating validity is known as interactive relative validity. Interactive relative validity is regarded as verified when these relative patterns are similar in the simulator experiments and the field values.

Finally, the effects of implementing certain changes at the intersection, as in scenario I would be observed. Data from scenario I would be compared to that of Scenario A. A distinct difference in deceleration and braking is expected to be observed between I and A, due to shifting the stop bar. If the results are as expected, it is a clear indication that the driving simulator could be used as a test bed, as it helps in identifying the problem as in Case A and also suggesting a solution the problem, as in cases I.

References

1. Abdel-Aty M. and Abdelwahab H. (2002), Artificial Neural Networks and logit Models for Traffic Safety Analysis of Toll Plazas, *Transportation Research Record 1784*, Paper no. 02-2270, pg 115-125.
2. Abdel-Aty M., Mohamed A. and Klodzinski J. (2001), Safety Considerations in Designing Electronic Toll Plazas: Case Study, *ITE Journal*, March 2001, pg 20-24
3. Blaauw, G., 1982. Driving experience and task demands in simulator and instrumented car: a validation study. Human Factors 24 (4), 473–486.
4. Tornros J. (1998), Driving Behaviour In A Real And A Simulated Road Tunnel-A Validation Study, *Accident Analysis and prevention*, Vol 30, No.4, pg 497-503.