Operational and Safety-Based Analysis of Toll Plaza Signage using Driving Simulation

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SAFETY RESEARCH USING SIMULATION UNIVERSITY TRANSPORTATION CENTER

Introduction

- Driver confusion when approaching toll plazas associated with signage location and proximity can create hazardous safety conditions, particularity for high speed freeways.
- This study presents the first prototype of a virtual simulation environment for a toll plaza. It was used in assessing the effectiveness of electronic toll collection lane types and how signage affects driver behavior and safety in toll plazas.
- The study consisted of two phases:
  - The initial phase conducted at UMass Amherst where the scenario was developed.
  - The second where the experiment was conducted using the driving simulator located at the University of Puerto Rico in Mayagüez.
- The variables taken into consideration were average speed and acceleration noise. The standard deviation of acceleration (acceleration noise) was used as a surrogate measure for crash frequency.

Objectives

- Evaluate whether implementing overhead signs better informs subject drivers and prevents drastic speed changes when approaching the toll plaza.
- Evaluate whether there is a difference in the subject drivers' behavior with respect to different sign configurations with different traffic flow conditions.
- Compare subject drivers' behavior for the different sign configurations during the day and night.

Experiment

- Subject-gender distribution 45% females and 55% males:
  - 18 to 25 years old: 40%
  - 26 to 55 years old: 35%
  - 56 to 70 years old: 25%
- Four decision areas (Areas 1- 4), two configurations and twelve scenarios were evaluated.
- Three different factors were simulated in each configuration, (traffic flow condition, destination lane at the toll plaza and starting lane position).

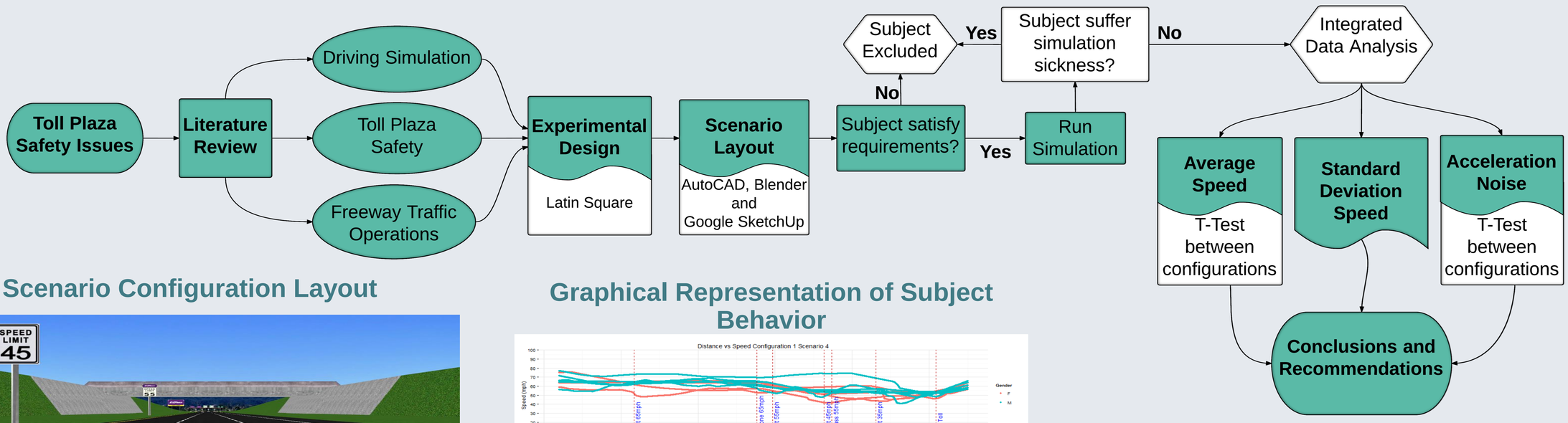
Equipment

- Desktop simulator configured as a cockpit simulator
- Portable and permanent simulator vehicle
- Scenario projectors and screens
- Operator station and the host computer hardware and software

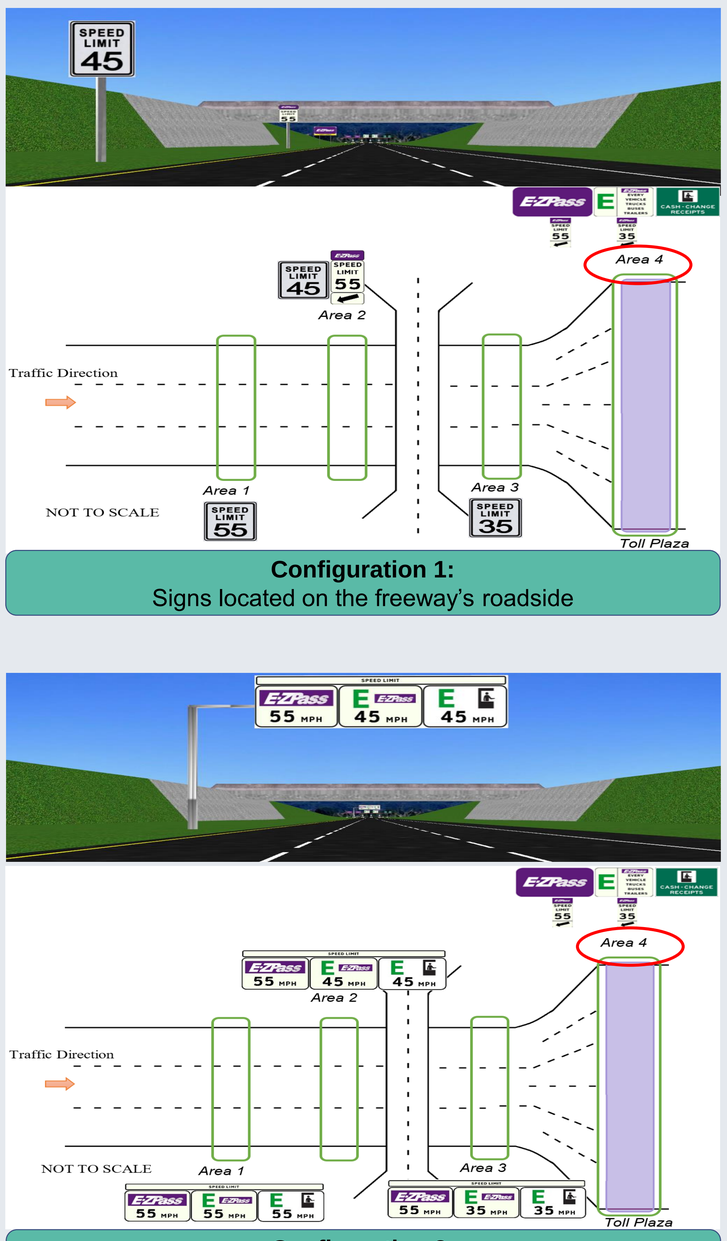
UPRM Transportation and Simulation (Laboratory Setup)

Subject driving the generic simulation before running the experiment scenarios

Methodology



Scenario Configuration Layout

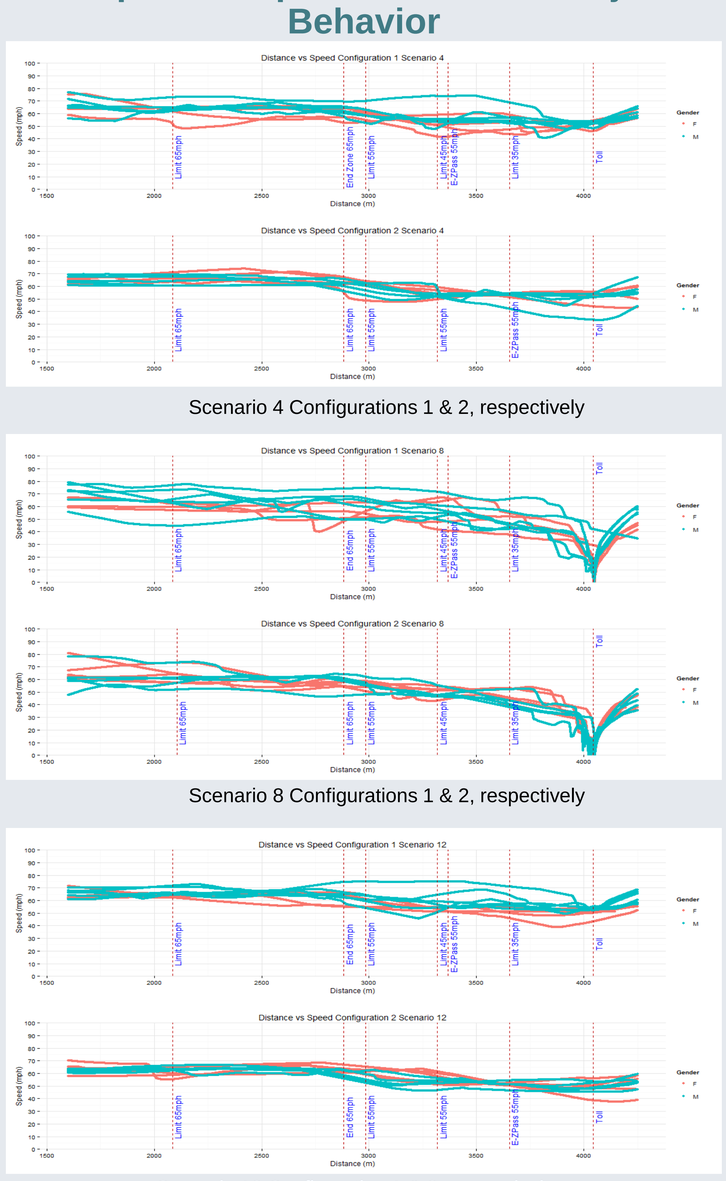


Configuration 1:
Signs located on the freeway's roadside

Configuration 2:
Overhead signs

Caguas Sur Toll Plaza

Graphical Representation of Subject Behavior



Scenario 4 Configurations 1 & 2, respectively

Scenario 8 Configurations 1 & 2, respectively

Scenario 12 Configuration 1 & 2, respectively

Scenarios Description

Scenario	Description
1	No Traffic, Start Left Lane, pass through E-Z Pass Lane
2	Lead Vehicle Only, Start Left Lane, pass through E-Z Pass Lane
3	No driver Ahead- Traffic Middle and Right Lane, Start Left Lane, pass through E-Z Pass Lane
4	Traffic for All Lanes, Start Left Lane, pass through E-Z Pass Lane
5	No Traffic, Start Left Lane, pass through Cash Lane
6	Lead Vehicle Only, Start Left Lane, pass through Cash Lane
7	No driver Ahead- Traffic for Middle and Right Lanes, Start Left Lane, pass through Cash Lane
8	Traffic for All Lanes, Start Left Lane, pass through Cash Lane
9	No Traffic, Start Right Lane, pass through E-Z Pass Lane
10	Lead Vehicle Only, Start Right Lane, pass through E-Z Pass Lane
11	No driver Ahead - Traffic for Middle and Right Lanes, Start Right Lane, pass through E-Z Pass Lane
12	Traffic for All Lanes, Start Left Lane, Night, pass through E-Z Pass Lane

Table 1

Area 4	Average Speed		Acceleration Noise	
Scenario	Configuration		Configuration	
	1	2	1	2
4	51.49	49.43	0.15	0.13
8	*24.39	*16.75	1.70	1.83
12	52.25	49.65	0.24	0.08

*** T test P-value <0.05**

Table 2

Acceleration Noise Comparison			
Scenario	Acceleration Noise (m/s²)		Difference between configuration 1 & 2 (%)
	Configuration 1	Configuration 2	
4	0.69	0.54	24
8	0.99	1.01	2
12	0.67	0.54	21

Relevant Findings

- In Scenarios 4, 8, and 12 the average speed is lower for configuration 2 than for configuration 1.
- In Scenario 8, Area 4, the comparison between configurations is significant.
- Incorporating a dedicated signage for nighttime driving improves driver behavior.
- Using the variable acceleration noise as a surrogate measure, an expected potential crash reduction of more than 60% can be achieved.

Conclusions

- Signage modifications for Configuration 2 will lead to improvements in driver behavior.
- When vehicle flow increases, the acceleration noise also increases, except in Configuration 2, where the acceleration noise decreases in all traffic flows.
- The proposed safety countermeasure has the potential to reduce the expected crash frequency up to 60%, including both day and nighttime scenarios.

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