The objective of this thesis is to explore the driving behavior at toll plazas by examining multiple scenarios using a driving simulator to study the effect of different options including different path decisions, various signage, existence of pavement markings, various traffic conditions, and extending auxiliary lanes before and after the toll plaza on the drivers' risk behavior. Also, this study focuses on investigating the effect of drivers' characteristics on the drivers' dangerous behavior (e.g., speed variation, sudden lane change, drivers' confusion). Safety and efficiency are the fundamental goals that transportation engineering is always seeking on highways. Transportation agencies have a crucial challenging task to accomplish traffic safety, particularly at the locations that have been identified as crash hotspots. In fact, toll plaza locations are one of the most critical and challenging areas that expressway agencies have to pay attention to because of the increasing traffic crashes over the past years near toll plazas.

Drivers are required to make excessive decisions at expressway toll plazas which result in drivers' confusion, speed variation, and sudden lane changing maneuvers. These crucial decisions are mainly influenced by three reasons. First, the limited distance between toll plazas and the merging areas at the on-ramps before the toll plazas. In addition to the limited distance between toll plazas and the diverging areas after the toll plazas at the off-ramps. Second, drivers' critical decisions are also affected by the location and the configuration of signage and pavement markings. Third, drivers' decisions are also affected by the different lane configurations and tolling systems that can cause drivers' confusion and stress. Nevertheless, only a limited number of studies have explored the factors that affect driving behavior and safety at toll plazas. There are three main systems of the toll plaza, the traditional mainline toll plaza (TMTP), the hybrid mainline toll plaza (HMTP), and the all-electronic toll collection (AETC). Recently, in order to improve the safety and the efficiency of the toll plazas, most of the traditional mainline toll plazas have been changed to the hybrid toll plazas or the all-electronic toll collection plazas. This study assessed driving behavior at a section, including a toll plaza on one of the main expressways in Central Florida. The toll plaza is located between a close on-ramp and a nearby off-ramp. Thus, these close distances have a significant effect on increasing the confusion and the sudden lane change maneuvers before and after the toll plaza.

Driving simulator experiments were used to study the driving behavior at, before and after the toll plaza. The details of the section and the plaza were accurately replicated in the simulator. In the driving simulator experiment, 72 participants were recruited from families, friends, colleagues, and volunteers with different age groups. Subsequently, each driver performed three separate scenarios out of a total of 24 scenarios. Seven risk indicators were extracted from the driving simulator experiment data by using MATLAB software. These variables are average speed, the standard deviation of speed, the standard deviation of lane deviation, acceleration rate, the standard deviation of acceleration (acceleration noise), deceleration rate, and the standard deviation of deceleration (variation of the braking action). Moreover, various scenario variables were tested in the driving simulator including different paths, signage, pavement markings, traffic condition, and extending auxiliary lanes before and after the toll plaza. Moreover, participants were asked to fill a questionnaire before and after each experiment to collect participants' characteristics and to check the discomfort or the sickness due to the simulator process for each participant. Another objective of this study is to explore the effect of drivers' individual characteristics on driving risk behavior. Nine variables were extracted from the simulation questionnaire representing individual characteristics including, age, gender, education level, annual income, crash experience, professional drivers, ETC-tag use, driving frequency, and novice international drivers.

A series of multivariate linear regression models with random effects to account for multiple observations from the same participant were developed to reveal the contributing factors for driving behavior at toll plazas. The results uncovered that all drivers on the path of the express lanes showed higher speed and lower speed variation, lane deviation, and acceleration noise than other paths with cash lanes. Also, the results revealed that providing adequate signage, and pavement markings are effective in reducing risky behavior at toll plazas. Drivers tend to drive with less lane deviation and acceleration noise before the toll plaza when installing pavement markings. Adding DMS sign at the on-ramp has a significant effect on reducing speed variation after the on-ramp. Likewise, removing the third overhead sign before the
toll plaza has an important influence on reducing risk behavior before and after the toll plaza. This result may reflect drivers' desire to feel less stress and confusion by excessive signs and markings. Third, extending auxiliary lanes with 660 feet (0.125 miles) before or after the toll plaza have effect on increasing the average speed and reducing the lane deviation and the speed variation before and at the toll plaza zone. It also has impact on increasing the acceleration noise and the braking action variation after the toll plaza. Finally, it was found that in congested conditions, participants drive with a lower speed variation and lane deviation before the toll plaza but with a higher acceleration noise after the toll plaza. On the other hand, understanding drivers' characteristics is particularly important for exploring their effect on drivers' risky behavior. Young drivers (18-25) and old drivers (older than 50 years) consistently showed a higher risk behavior than middle age drivers (35 to 50). Also, it was found that male drivers are more dangerous than female drivers at toll plazas. Drivers with high education level, drivers with high income, novice international drivers, ETC-tag users, and drivers with driving frequency less than 3 trips per day are more cautious and tend to drive at a lower speed. Likewise, professional drivers and drivers with crash history showed higher speed variation. Lastly, the study confirmed that driving simulator experiments are a cost-effective, safe, and efficient way for exploring various scenarios for highway operations and safety.

Major: Civil Engineering

Educational Career:
Bachelor's of Civil Engineering, BS, 2012, Alexandria University

Committee in Charge:
Mohamed Abdel—Aty, Chair, Civil, Environmental, and construction Engineering
Naveen Eluru, Civil, Environmental, and Construction Engineering Department
Jaeyoung Lee, Civil, Environmental, and Construction Engineering Department

Approved for distribution by Mohamed Abdel-Aty, Committee Chair, on August 2, 2016.

The public is welcome to attend.