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DEVELOPING A VR TRAINING MODEL FOR IMPROVING TRANSPORTATION SAFETY PROTOCOLS FOR RURAL AREAS

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DEVELOPING A VR TRAINING MODEL FOR IMPROVING TRANSPORTATION SAFETY PROTOCOLS FOR RURAL AREAS

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ABSTRACT

This research evaluated the effectiveness of using simulated virtual reality driving environments to improve transportation safety in rural areas. The transportation accident fatality rate is more than double the national average in rural areas and highlights an important opportunity to address these challenges through improved safety protocols and investments. A review of the literature revealed high frequency scenarios that contributed the most to fatality or injury accidents. Virtual reality driving simulations were created based on these high frequency events using a specified rural roadway identified with the assistance of the Missouri Department of Transportation. Scenarios considered weather-related conditions, such as flooding or snowfall, along with wildlife crossings, as part of the virtual training. Engineering managers in state or county departments of transportation can use this research to develop training protocols with community planners in rural regions. The research work was sponsored by the Mid-America Transportation Center (MATC).

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LIST OF ABBREVIATIONS

Analysis of Variance (ANOVA)

Available Sight Distance (ASD)

Federal Highway Administration (FHWA)

Geographic Information System (GIS)

Industry Foundation Classes (IFC)

Mid - America Transportation Center (MATC)

Missouri Department of Transportation (MoDOT)

National Highway Traffic Safety Administration (NHTSA)

Three Dimensional (3D)

Transportation research international documentation (TRID)

Virtual Environment for Reactor Analysis (VERA)

Virtual Reality (VR)

1. INTRODUCTION

The rate of traffic accidents globally has resulted in an enormous loss of lives and properties. It is a problem that results in physical, emotional, and mental damage to the victims, and their families. These accidents also cause governmental economic losses, costing them billions of dollars per year. In the United States of America, with 19% of the population living in rural areas, the rate of traffic fatalities in rural areas is twice the rate in urban areas (National Highway Traffic Safety Administration, 2020), and rural roads recording 43% of the total roadway fatalities (Federal Highway Administration, 2020). This research creates a tool to evaluate drivers in different immersive environments that will allow for comparative analysis of training effectiveness.

2. LITERATURE REVIEW

Previous researchers have conducted studies to improve transportation safety using various methods like driving simulators, real-life/real time experiments, virtual reality applications, and others. However, only the minority of studies considered evaluating the effectiveness of these methods in providing/ improving transportation safety with focus on rural areas. Some of the research studies used Virtual Reality (VR) simulators or traditional driving simulators to access drivers' behaviors and applied some causes of road fatalities like work zones, wildlife crossing, inclement weather, bad roads, large farm vehicles/implements, road geometry and other primary and precipitating factors to virtually simulated environments. The main question around which this research project was built was: Is the Virtual Reality (VR) simulator or the traditional driving simulator most effective?

2.1. WORK ZONES

Various metrics were applied by researchers; however, one study performed by Banerjee et al, 2019, was an experimental evaluation of work zones barrier capacities to influence driver performance on a freeway with the use of a medium-fidelity full-scale driving simulator. They noted that the Federal Highway Administration recorded that for every 5.4 minutes of the day, one work-zone crash occurred in America (FHWA, 2015). The work zones barriers used for their experiment included cone pylons, concrete jersey barriers, and metal barriers. Sixty-Five persons participated in the experiment and the traffic volumes were based on level of service C. Banerjee et al (2019) observed that drivers deviated away from concrete jersey barriers, and from the center of the lane which negates driver behavior in a previous study on an arterial road. Conclusions were reached utilizing a single factor analysis of variance (ANOVA) that pointed out a statistically significant difference between the mean speeds of vehicles across all barriers and across metal barriers for individuals of age group 35 and above against other age groups (Banerjee & Jeihani, 2019).

Another paper by McAvoy et al (2007) focused on validating the use of driving simulators to determine the impact of temporary traffic control devices in a work zone at night. A combination field study and simulator study was conducted; they surveyed six sites and used One hundred and twenty-seven (127) human objects, respectively. Speed studies were carried out in three separate locations in the freeway work zone; they include the beginning of the work zone near the transition area, the middle of the work zone, and the end of the work zone near the downstream taper. The authors evaluated the data with analysis of variance test to compare driver performance in the field versus the simulator. The study concluded that driving simulators did not replicate the mean speeds observed in the field because of driver's perceived risk of work zones at nighttime (McAvoy, Schattler, and Datta, 2007).

2.2. WILDLIFE CROSSING

Stanley et al (2006) evaluated the effectiveness of enhanced wildlife advisories on drivers' behavior using simulated driving environments to reduce animal-vehicle collision. Traffic accidents involving collision with animals are becoming a major concern as human activities are gradually interfering with wildlife (Stanley et al, 2006).

Several measures were implemented to reduce the incidence of animal-vehicle collision but only fencing and creating of wildlife passages showed effectiveness (Stanley, Hardy, and Lassacher, 2006). However, due to the inflated cost and maintenance of the fences, other alternatives are of high interest to transportation agencies. In their study, a variable message sign and two standard signs with a flashing beacon attached to one were used in the simulations to alert drivers when they approached areas known for animal crossing. The standard signs displayed the text “NEXT 20 MILES” and the variable message sign displayed the text “ANIMAL CROSSING NEXT 20 MILES BE ALERT”. The standard sign with flashing beacon influenced drivers more than the standard sign without beacon, it caused a slight reduction in the speed of vehicles. The variable message sign in combination with a standard sign with flashing beacon was identified as the most promising advisory system combination because it provided the highest level of adherence which led to the fewest collisions (Stanley, Hardy, and Lassacher, 2006).

2.3. ROADWAY DESIGN AND GEOMETRY

Road geometry affects road users in numerous ways, for example, available sight distance. A research study was carried out by Bassani et al (2019) to examine the impact of available sight distance on driver behavior along rural highways, using driving simulation. Available sight distance (ASD) is an underlying factor in principles of road geometry, and it is used by road designers to ensure road safety, yet designers do not know the effect of a specific available sight distance on the longitudinal and transversal behavior of drivers involved in negotiating curves (Bassani et al, 2019). This study analyzed longitudinal behavior of drivers and was conducted along rural highways curves with limited visibility. A driving simulator was used to recreate and design and test sight conditions that had three tracks with several combinations of radii and sight obstructions, which resulted in minimum available sight distance of 56.6m. Traffic barriers, speed limit signs, vegetation and other road factors that could alter drivers' perceptions were removed from the simulation. Results showed that speed and trajectory dispersion from the lane centerline linearly depended on ASD in the investigated range of curve radii. Bassani et al (2019) suggested that when seeking to encourage drivers to incorporate good behavior, road designers should make adjustments to the available sight distance. Overall, to develop safe driving conditions, their study suggested ASD should be designed to be slightly greater than the required sight distance because, excessive ASD values can potentially encourage driver to drive at inappropriate speeds (Bassani, Catani, Salussolia, and Yang, 2019).

In another study, Lee et al (2011) designed a project to address problems associated with roadway design and geometry with the aid of driving simulators. Though driving simulators can be a helpful system for field research, their capacity to support traffic engineers and geometry designers in addressing issues related to road design projects is yet to be confirmed (Lee et al, 2011). In their study, the authors discussed a framework focused on design by which driving simulators could be useful to road design engineers. There were several drawbacks associated with the use of driving simulators for roadway design. The drawbacks included perceptual differences among road safety researchers and engineers, on how simulators can be used. To address this, interviews were conducted with engineers which helped resolve perceptual differences, and it was useful in identifying other issues simulators could address. Another drawback was driving simulators were mostly defined as high fidelity. Clarity was gained on the meaning of simulator fidelity, linking it with road design issues, after a survey on simulators and simulator characteristics. The third drawback identified was that the data collected by traffic engineers did not match the data from simulators (Lee, McGehee, Brown, Richard, Ahmad, Ward, Hallmark & Lee, J. 2011). This could be traced to insufficient simulator fidelity, but it could also be a result from other primary sources, like the differences in traffic engineers' focus times and simulator researchers. Overall, the issues associated with using driving simulators in addressing roadway design resulted from both technical and communication challenges (Lee, McGehee, Brown, Richard, Ahmad, Ward, Hallmark and Lee, J. 2011).

In a recent study by Sheta et al (2020) they aimed at facilitating the analyses of driver behavior on several curves scenarios by producing continuous driver behavior profile using a driver simulator. Other studies conducted field research to better the consistency in highway design for reducing the rate of traffic accidents (Sheta et al, 2020). The relationship between traffic fatalities and environmental sustainability was strong in terms of emissions and natural resources consumption. In their study, a two-lane rural highway was studied to determine the effect of spiral transition curves on drivers' behavior regarding speed and lateral position with changing geometric feature of horizontal curves. Seventy-two (72) individuals were recruited for the study, and they drove on forty-eight (48) different curves (Sheta, Foda, and Montella, 2020). Driver speed behavior was studied at 5 strategic locations on every curve, and the effect of spiral was studied using 3 approaches: changing radius, deflection angle, and direction of the curve. Results showed that the spiral curves had significance in small radii curves and sharp deflection angles by increasing the average speed at the curves and reduction in the tangent to curve speed (Sheta, Foda, and Montella, 2020).

Monajjem et al (2019) evaluated the effects of new treatments and approached traffic driver performance on a combined horizontal and crest vertical curves of two-lane rural roads. They noted that high percentage of crashes occurs due to drivers' distorted perception of road characteristics, specifically on mountainous rural two-lane roads with several curves. In their study, they utilized a driving simulator to assess driver performance when treatment was applied and when it was not in the scope of free flow traffic and head-on traffic roads. Monajjem et al (2019) identified factors used to measure driver's performance from the simulation that included mean acceleration and the angle of the steering wheel. After performing statistical tests, the results showed that the combination of chevrons and a warning signal amounted to lower speed and steering wheel angle, yet sealed shoulder reduced neither speed nor the angle of steering wheel. In conclusion, the results suggested that a warning signal is most the adequate treatment for horizontal and crest vertical curves and should be adopted before combined crest curves (Monajjem, Kazemzadehazad, and Larue, 2019).

2.4. SPEEDING BEHAVIOR

Montella et al (2014) in their research utilized virtual environment for reactor analysis (VERA) high-fidelity dynamic-driving simulator to examine the continuous speed profiles of different drivers on a two-lane rural highway. Studies designed models for predicting operating speed and evaluated drivers' speed behavior to enhance consistency in design of old and new roads (Montella et al 2014). Most of the models used were built based on spot speed data assuming constant operation speed throughout the horizontal curves and occurrence of acceleration and deceleration only on tangents. The aim of Montella et al.'s study was to succeed the limitations faced with these hypotheses (2014). The authors designed an experimental route consisting of the successions of 20 tangents, 1000m in length and curves with radii of 400m. It was observed that along the curve, the speed was not constant, and the rates of deceleration were significantly more than the rates of acceleration. After analyzing each driver's behavior, the results revealed that 85% of individual driver's speed reduction was more than two times the operating speed difference in the tangent-to-curve transition. The results showed that there was a potential to identify supplementary design inconsistencies and safety related issues after the analysis of individual speed profiles because it added crucial information to the analysis of the operating speed profile (Montella, Galante, Imbriani, Mauriello, and Pernetti, 2014).

2.5. INCLEMENT WEATHER

Wang et al.'s study (2020) was designed to achieve three goals. The first goal was to investigate the effects of driver's physiological performance on their speed choices, considering the level of visibility under fog conditions and the horizontal and vertical alignment of a rural road. Secondly, to measure the relationship between these variables. Lastly, to calculate the maximum acceptable speed that matched the drivers' physiological tolerance threshold. Their study was conducted using a driving simulation, thirty (30) individuals participated in the driving test. The interrelation between normal heart rate, driving speed, visibility, radius, and gradient were measured using multiple linear regression model. Results showed that normalized heart rate was affected by driving speed, visibility, radius of curvature and gradient. In general, the study revealed a substantial association between the drivers' physiological performances and the driving speeds under fog conditions (Wang, Zhang, Feng, Sze, Hu, and Wang, 2020).

2.6. DRIVING SIMULATOR VALIDATION

Driving simulators can be useful tools to help road design engineers outline and examine other road configurations that match driver expectations and increase the probability that drivers react appropriately (Granda, Davis, Inman, and Molino, 2011). This is applicable to roads that are still in early stages of development. The geometry of roads is an important factor for road safety and mobility; therefore, design engineers must have drivers in mind when designing roadways. In a research project by Granda et al. (2011) physical and functional parameters were discussed in terms of computer hardware, mechanical setup, software requirements, and rendition of visual imagery to help identify the parameters for the geometric research using a driving simulator. Applied research examples were also used for the setup, and they were accompanied by discussing issues associated with using driving simulators to evaluate the geometries of highways. The examples included pros and cons of driving simulators, validation of driving simulators, and simulator sickness (Granda, Davis, Inman, & Molino, 2011). Some of the mentioned pros and cons to using driving simulators for evaluating driver behavior to roadway geometrics included:

2.6.1. Pros and Cons.

Pros.

- Unique and/or non-existent roadways can be created, developed, driven, and investigated interactively
- Drivers can be subjected to countermeasures that might be dangerous on real roads
- Roadway designers can visualize and test alternative roadway geometric before construction
- Drivers can be subjected to countermeasures that are more expensive to test on real roads
- Experimental control over the roadway scenario, the treatment, and the control conditions

Cons.

- The vehicle dynamics associated with complex roadway geometries cannot be fully experienced
- The cost of developing the scenario can be initially high
- The manipulation of roadway geometries, especially complex ones, can induce simulator sickness

2.6.2.Validation of Driving Simulator. Granda et al. (2011) pointed out three basic classes of driving simulator validity, including: face validity, validity for a particular research area, and study-specific validity. Face validity, according to Fildes et al (1997) assumed that the performances in the simulator would be relatively like on-road performance due to the physical similarities that existed between the simulation and the real world. Demonstrating these physical similarities were sufficient to establish face validity (Fildes, Godley, Triggs, and Jarvis, 1997).

When validating a driving simulator for a particular research area, experiments are conducted that covered the types of tasks and measures to be evaluated such as the effect of independent variables on driver speed (Bella, 2005; Godley, Triggs, and Fildes, 2002). It can be adopted in this type of validation that once absolute or relative validity between real-world and simulation tasks were established, further validation was not necessary, or it may be periodically confirmed. In the study's specific approach to validation, it was assumed that any simulation study required real-world validation. When considering different research topics and novel driver tasks, it was not assumed that the validation can be established across a series of studies, even if they were in the same general area of research.

Yannis et al (2017) under normal and simulation driving conditions, compared the driving performance of young drivers. Thirty-one (31) young drivers within the age group of 20 to 30 years participated in the driving test which included participants using driving simulators and drivers in real traffic conditions. The real-life driving test took place at an interurban road, and the simulated scenario was designed with high precision to represent an interurban road. Lognormal regression models were used to perform statistical analyses to identify the effect driving environmental conditions both real and simulated, driver characteristics (age, gender, mileage) and driving performance measures to average vehicle speed change (Yannis, Papantoniou, and Nikas, 2017). The results of the analysis showed that absolute values of drivers' traffic performance varied between simulated and real driving conditions. Overall results showed a clear view of the length and the way in which driving conditions and driver's characteristics affected driving performance, and they give a substantial explanation for the reliance on specific simulator measurements (Yannis, Papantoniou, and Nikas, 2017).

Another paper by McAvoy et al. (2017) focused on validating the use of driving simulator to determine the impact of temporary traffic control devices in a work zone at night. The study concluded that driving simulators may not replicate the mean speeds observed in the field because of driver's perceived risk of work zones at nighttime (McAvoy, Schattler & Datta 2007).

2.7. DESIGNING OF SIMULATED SCENARIOS

A research project was conducted to develop a framework for the recreation of faster virtual scenes using Industry Foundation Classes (IFC)- based file. In the project, the authors (Dols et al., 2021) pointed out that it is not enough for road engineers to comply with guidelines to virtually recreate and to test their roads for improvement and safety. The authors suggested that efforts towards the recreation of the roads and its environment represented a real difficulty. One crucial setback resulted from the differences in the inputted data collected from different sources and required specific adaptations for every individual simulator (Dols, Molina, Camacho-Torregrosa, Llopis-Castelló, and García, 2021). The method used in their study was compared with two other methods for developing driving scenarios. The results revealed that virtual scenes were designed faster and were used to conduct safety audits, using driving simulators with data exchange file in IFC format. Dols et al. (2021) suggested that with the aid of a Building Information Modeling (BIM) model, the editing, programming, and processing times were reduced using the IFC data exchange format. Overall, this method proved to be cost efficient, and it enhanced the execution and optimization of resources in road safety analysis (Dols, Molina, Camacho-Torregrosa, Llopis-Castelló, and García, 2021).

Another author, Dols et al. (2016) conducted an experiment to show a new method for the design and development of driving simulator scenarios for road validation. A low-cost simulator that enabled a fast implementation and a new effective methodology for validation studies of different road was developed through the implementation of the simulator scenarios of existing roads (Dols, Molina, Camacho, Marín-Morales, Pérez-Zuriaga, and Garcia, 2016). This methodology was developed by the Institute of Design and Manufacturing (IDF) of the Polytechnic University of Valencia (UPV) in collaboration with the Engineering Research Group Highway (GIIC) of the UPV. Based on the analysis of a layers-file system, the methodology described herein allowed for the creation of new scenarios. The geometric design software enhanced a rapid development of simulated scenario, which made it easy for consulting firms using the system to evaluate specific route, get authentic results at reduced costs, even if the road is not yet built. Dols et al. (2016) discussed the basic structure of the layers generated for creating scenarios and guidelines for the implementation. This study described in detail the application of this methodology for successful results.

After an exhaustive literature review of available resources, the evident gap was: most of the research studies focused on drivers' behaviors in different scenarios using simulated environments in comparison to the real-world scenarios. However, some studies were conducted particularly focusing on the importance of the effectiveness of both virtual reality and driver simulator using simulated environments. Therefore, in this study, we investigated these methods by comparing the results obtained using a virtual reality simulator and a traditional driving simulator. The results from the experimental comparisons can be used for further study on transportation safety. Engineering managers in state or county departments of transportation can also use this research to develop training protocols with community planners in rural regions.

3. METHODOLOGY

The aim of this research was to determine the effectiveness of using Virtual Reality and a driving simulator for improving transportation safety in rural areas and to compare the results to determine which method is most effective in providing safety using simulated virtual reality driving environments. The research project focused on a sample location in a rural area of Missouri. Figure 3.1 shows the layout of the methodology used to accumulate data, build a road model (simulated virtual reality environment), and conduct the driving experiment to determine the most effective method between using virtual reality simulator and traditional driving simulator. The Literature Review was the first step carried out in the process, and it involved a comprehensive review of published papers relevant to the subject of transportation safety in rural areas using databases such as Transportation Research International Documentation (TRID), Google Scholar, Transportation Research Record, and others. Secondly, a survey of the modeled road was done, and a field observation was carried out in a location prone to periodical flooding in Missouri. The third step involved collecting data for measurements of land elevation and other features using ArcGIS Pro and Google Earth. In the next step, the road was designed based on the real location with various features identified on the field using Unity (A Cross-Platform Game Engine/Real-Time Development Platform).

Figure 3.1 Layout Figure of Methodology

3.1. LITERATURE REVIEW

See the comprehensive Review of Literature on page 2.

3.2. FIELD OBSERVATION

A rural area was selected for the experiment based on suggestions given by area engineer from Missouri Department of transportation – Central District St. James, MO. The recommended location—Route N in Crawford County— was selected due to presence of deer migration, blind curves, and its proneness to periodical flooding. Route N connects to I-44 in Bourbon and heads southeast over to Route 185 in Washington County. During the visit to the selected site, three locations on the roadway with high frequency and longer duration of flooding were identified. They included Route N (Figure 3.2) at Blue Springs Creek (crossing), Route N just west of Meramec River and Route N at Whites Creek (near the Crawford/Washington County Line).

Three Deer were seen crossing the road during the survey of the roadway. In the survey, features of the surrounding environment were noted. Some of the features (refer to Figure 3.3-3.6) sighted included, but were not limited to, trees, and vegetation, a river (Meramec River), creeks (Brazil Creek, Whites Creek, Blue Spring Creeks), lakes (Bluff Lake, Von Hoffman Lake), hills, farmlands, and bridges.

Figure 3.2 Snapshot of Route N (During Field Survey)

Figure 3.3 Area of Periodic Flooding

a

b

Figure 3.4 Meramec River. a). Signpost of Meramec River. b). Road view of Meramec River.

a

b

Figure 3.5 Blue Spring Creek. a). Signpost of Blue Spring Creek. b) Side view of Blue Spring Creek.

a

b

Figure 3.6 Hills/Farmland a). Road view Hills/Farmland. b). Farmland with a lake.

a

b

Figure 3.7 Route N via Google Earth. a) Satellite view of Route N. b). Location of Route N via Google Earth.

Figure 3.8 Blue Springs Creek Crossing Route N (Area of Periodic Flooding).

Figure 3.9 Meramec River - Route N (Area of Periodic Flooding).

Figure 3.10 Whites Creek Crossing Route N (Area of Periodic Flooding).

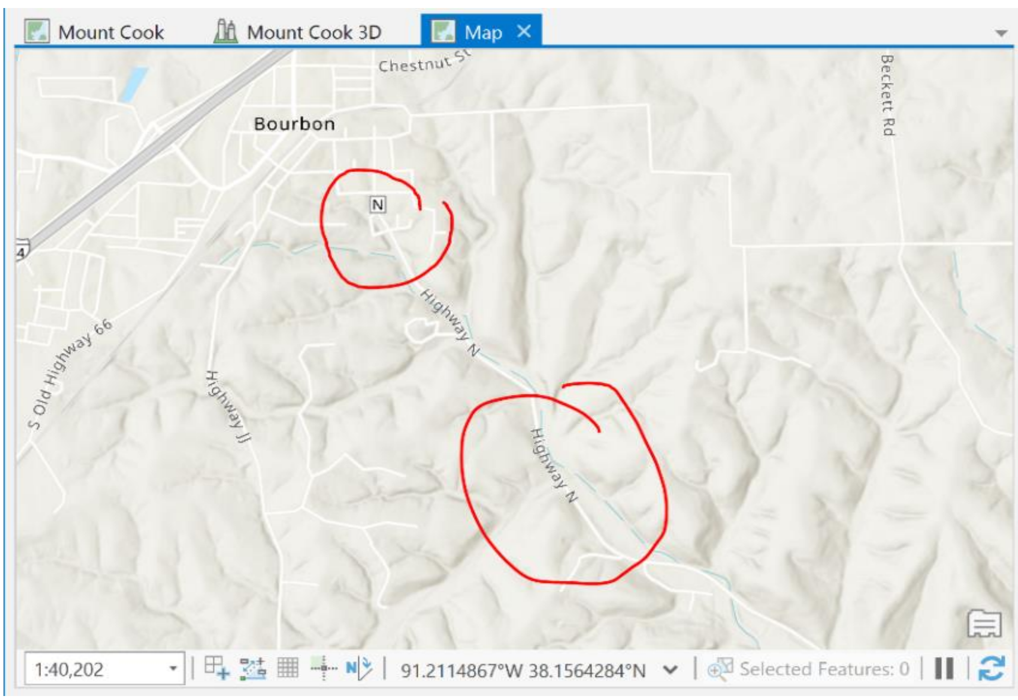

Figure 3.11 Topography of Route N via ArcGIS.

3.3. DATA ACQUISITION

The databases used for further study of Route N included ArcGIS and Google Earth. The geographic landscape of Route N (Figure 3.7) and areas of periodic flooding (Figure 3.8 – 3.10) were acquired from Google Earth database. The elevation data of the roadway were obtained using ArcGIS (Figure 3.11). The data collected was then used for the design of the model.

3.4. ROAD MODELING – DESIGNING

In this research project, Unity Real-Time Development Platform (3D) was used to model the site and Visual Studio with C# (Figure 4.4) was used to modify/program the controls for the simulation. The first step was to design the roadway using parameters obtained from the database, and field observations. The second step was to define the features of the environment which included trees/vegetation, traffic signs, highlands and lowlands, creeks, and river.

3.4.1. Trees/ Vegetation. The trees used in this simulated environment were purchased from a developer via Unity Asset Store. Two 3D trees with ambient occlusion were selected for this project because they have similar in shape and height to the trees found along Route N. In the environment model, trees were placed all through the simulated road because only a portion of Route N was modeled, and the portion selected throughout the stretch. Figure 3.12 shows the image of the simulated environment with trees along the road.

3.4.2. Highlands and Lowlands. During the field survey, farmlands, barns, hills, and low plains were observed (Figure 3.6) but after careful consideration, the researchers decided to exclude those features in the simulation. The reason was the hills and plains with farmlands had little significance to the purpose of the project and they were absent along the part of Route N chosen and merged.

3.4.3. Creeks. With the survey in combination with tools like Google Earth and ArcGIS, creeks along route N were discovered, such as Brazil Creek, Whites Creek, and Blue Spring Creeks. For this experiment, Whites Creek and Blue Spring Creek were chosen. The rationale behind the decision was that these two creeks are known for periodic flooding and they both cross Route N during flooding stages. Figure 3.12 shows a creek crossing Route N at the beginning of potential flood occurrence

3.4.4. River. Figure 3.13 shows Meramec River in the simulated environment of Route N; metal guard rails were used on the side of the road, on the bridge, and over the river to mirror barriers on the bridge at Meramec River. The researchers decided to raise the level of the water at the river to make the river visible to drivers and to represent rising water level because of flooding or potential flooding.

3.4.5. Traffic Signs. Traffic signs were chosen and placed along the road based on drivers' needs. None of the signs were placed according to standards or based on the exact signs found on Route N. They were chosen to inform drivers about road hazards ahead, and road geometry and required speed limits were considered and implemented along the simulated road to enhance drivers' experiences. Figure 3.14 shows three traffic signs: animal crossing, slippery road, and curve road to the left. The animal crossing sign was chosen to alert drivers of potential crossing of animal along that path, the slippery road sign informed drivers about the condition on the road, especially due to flooding to minimize risks of accidents. The left curve sign was placed to inform drivers of the paths' geometry also help drivers reduce their speeds

Figure 3.12 Simulated Creek with sign of potential Flooding.

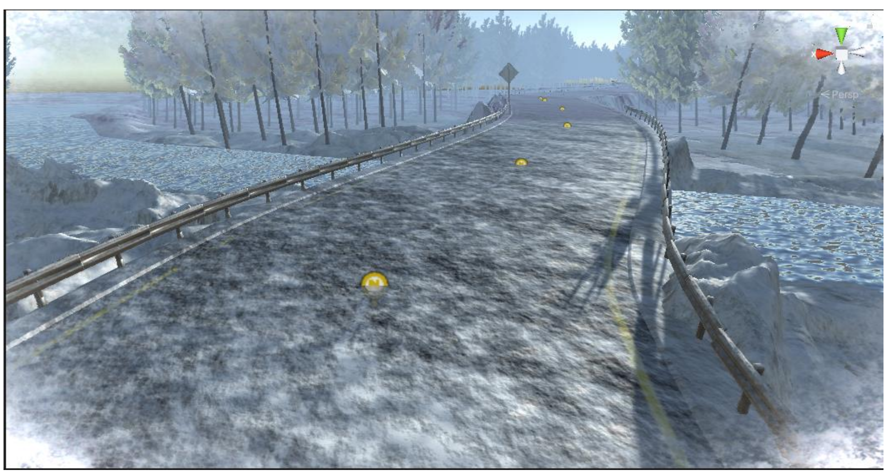

Figure 3.13 Model of Meramec River.

Finally, a realistic 3D car was imported into the simulated virtual reality roadway for the driving experiment.

Figure 3.14 Simulated Virtual Reality Roadway with a Car.

3.5. EXPERIMENT

For this research project, two techniques were applied to conduct the transportation safety experiment and the results from both were compared for further analysis. The methods for evaluation were:

- Virtual Reality Hardware
- Traditional Driving Simulator

The Results and Discussion section described how drivers' behavior and performance will be evaluated in the presence of the different threat elements considered such as snowfall, flooding, animal crossing and blind curves.

4. RESULTS AND DISCUSSION

The hazards particular to the studied site were modeled. They include, snowfall, flooding, animal crossing and blind curves.

4.1. SNOWFALL

The first hazard simulated in the model was snowfall. As commonly known, snow and ice contribute to yearly accidents. Snow reduces the friction between the tires of cars and the road, and it causes foggy weather conditions that reduce driver vision/road visibility. The asset used to achieve Figure 4.1 (Simulated snowfall) is called Global Snow. The simulation was done by attaching the Global Snow script to the Main Camera in the Multipurpose Camera Rig. The intensity, snow size, and other features were adjusted to obtain desired result. For the experiment, the researchers enabled terrain marks and footprints features to show effect and marks on the road when the car drove through the snow filled road and when brakes were applied. This study looked out for sliding off the road either due to speeding or delayed braking.

4.2. FLOODING

A picture representing a flooded creek in route N is shown in Figure 4.2. Flooding was chosen as a hazard because Route N is known to flood periodically at specific locations. For this experiment, it was important to understand driver behavior around flooded environment. Drivers were expected to stop when they approached a flooded road because they are unaware of what may be underneath, and in this case, the researchers did not have a scale in the simulated environment to measure the water levels. Though drivers were not expected to proceed or drive through the flooded area, the researchers wanted to know drivers' perceptions of the flooded area and the water level, as well as the decision made by each driver (Drive-through or halt). In modeling the representation of a flooded creek, this study created a stagnant water portion over the path where the creek crosses the road. This was achieved this by applying three layers of stagnant water using an asset purchased from Unity Asset Store called Standard Asset (Water4AdvancedReflection). This flood simulation was applied to the two creeks in the simulated environments (Blue Spring and Whites Creeks) except for the Meramec River. The reason for excluding Meramec River flooding was because the average flooding scenario increased the water level at the Meramec, but it did not necessarily make it overflow the riverbank.

Figure 4.1 Simulated Snowfall.

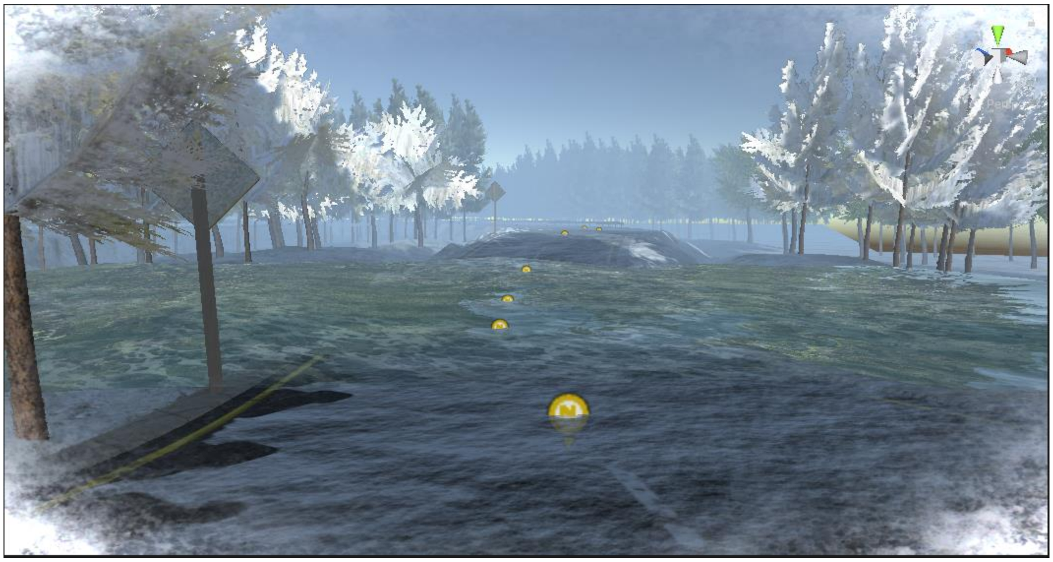

Figure 4.2 Flooded Creek Simulation.

4.3. ANIMAL CROSSING

For this experiment, we chose deer (see Figure 4.3 – 4.4) because during the site survey, the researchers saw three deer crossing Route N. The asset Deer Animated was purchased from Unity Asset Store and was chosen because of the available animation varieties. Among the animations were idle state, eating, walking, jumping, and galloping. The animations were achieved by writing scripts (performed by C# on Visual Studio shown in Figure) using key binds for each desired motion. The point of interest was drivers' behaviors when they see the deer crossing the road. Some of the metrics for assessing the driver's behavior were A. adherence to the animal crossing sign; in this case the researchers looked for change in speed, deceleration or acceleration or constant speed by drivers. B. If drivers halted when they saw the deer, the researchers wanted to know the rate of deceleration and the distance between the car and the deer when the driver fully stopped. C. In a case when the driver hit the deer, the researchers were interested in the driver speed at the time of the accident, driver perception in relation to the when they saw the deer, and available sight distance.

Figure 4.3 Simulation View of Wildlife Crossing.

4.4. BLIND CURVES

The last hazard considered was a problem associated with the geometry of the road in relation to the environment. On Route N, the researchers drove through blind curves in which the trees and vegetations on the side of the road obstructed driver's complete visibility of what lies ahead around the curve. For safety reasons, the researchers positioned a right curve sign to alert drivers of the road geometry (Figure 4.5). This part can be used to assess driver behavior with respect to adherence to sign. Drivers were expected to slow down when approaching the curve, but the experiment provided information about the perception of drivers when maneuvering around such curves.

Miscellaneous Files　　Deer

```
using UnityEngine;
using System.Collections;

public class Deer : MonoBehaviour {
    public Animator deer;
    private IEnumerator coroutine;
    public ParticleSystem dust;
    public ParticleSystem dustgallop;
    // Use this for initialization
    void Start () {

    }

    // Update is called once per frame
    void Update () {
        if (Input.GetKey(KeyCode.S))
        {
            deer.SetBool("idle", true);
            deer.SetBool("walking", false);
            deer.SetBool("turnleft", false);
            deer.SetBool("turnright", false);
            deer.SetBool("trotting", false);
            deer.SetBool("trotleft", false);
            deer.SetBool("trotright", false);
            deer.SetBool("galloping", false);
            deer.SetBool("eating", false);
            deer.SetBool("jumping", false);
            deer.SetBool("galloping", false);
            dust.GetComponent<ParticleSystem>().enableEmission = false;
            dustgallop.GetComponent<ParticleSystem>().enableEmission = false;
        }
        if (Input.GetKey(KeyCode.W))
        {
            deer.SetBool("walking", true);
            deer.SetBool("backward", false);
            deer.SetBool("trotting", false);
            deer.SetBool("galloping", false);
            deer.SetBool("eating", false);
            deer.SetBool("up", false);
            deer.SetBool("idle", false);
            deer.SetBool("jumping", false);
            dust.GetComponent<ParticleSystem>().enableEmission = false;
            dustgallop.GetComponent<ParticleSystem>().enableEmission = false;
        }
```

Figure 4.4 Deer Animation Script.

Figure 4.5 Example Blind Curve in the Simulated Environment.

5. CONCLUSIONS

Virtual reality (VR) and traditional driving simulators with simulated virtual environments are effective for improving transportation safety in rural areas. Route N in Bourbon, Missouri was selected for the road simulation development. Unity Real-Time Development Platform was use in the design and development of the simulation. Several hazards particular to this route were modeled in the simulated environment to enhance the evaluation of driver behavior along the route. The dataset used to develop the model were gathered from Site Surveys, ArcGIS, and Google Earth.

Although no experiment was performed, the built simulation assisted in the task of evaluating VR systems and driving simulators for improving transportation safety. The simulation can be tuned to fit future needs of simulated road projects. This gives flexibility to future users of the model when in need different or specific features in the model. In addition, engineers in state or county department of transportation can use this model for training purposes and other community planning activities.

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