Virtual Reality Platform for Sustainable Road Education among Users of Urban Mobility in Cuenca, Ecuador

Gabriel A. León-Paredes[1], Omar G. Bravo-Quezada[1], Erwin J. Sacoto-Cabrera[1], Wilson F. Calle-Siavichay[1]
Ledys L. Jiménez-González[2], and Juan Aguirre-Benalcazar[3]
Universidad Politécnica Salesiana, Cuenca - Ecuador[1]
Instituto Tecnológico Sudamericano, Cuenca - Ecuador[2]
Empresa Pública Municipal de Movilidad, Tránsito y Transporte de Cuenca, Cuenca - Ecuador[3]

***Abstract*—A traffic accident is an event generated in an unforeseen way that is beyond the control of the people involved, which can produce bodily, functional, or organic injuries, leading to death or disability in the worst cases. According to the *Empresa Pública Municipal de Movilidad, Tránsito y Transporte de Cuenca* (EMOV-EP), the total accidents recorded in 2021 were, 24.97% due to ignoring traffic signs, 21.11% due to not paying attention to traffic, and 16.94% due to driving under the influence of alcohol. The EMOV-EP, is the responsible for the regulation of human mobility. Thus, the EMOV-EP in conjunction with the *Universidad Politécnica Salesiana* (UPS) have introduced the next research question: How can a road safety education strategy, supported by Information and Communication Technologies (ICTs), can be developed to contribute to the improvement of the behavior of citizens to increase their knowledge of the traffic laws and regulations, and thus reduce the number of accidents in the city of Cuenca? Furthermore, in this paper we present the development of a Virtual Reality (VR) platform designed for road safety education. The platform is composed of a Web system, and 4 VR systems (games) that have been designed for 4 common causes of accidents respectively (drunk drivers, high-speed drivers, cyclists riding in bicycle lanes, and users of the tram transport system), using a serious games approach and the Oculus Rift/Quest technology. We have found that more than 80% of users have had a very good experience of playing and learning through the VR systems. Hence, this virtual reality platform constitutes a technological proposal with social impact because it creates an entertainment environment that can raise awareness among citizens, thereby strengthening road safety education and reducing the number of accidents in the city of Cuenca.**

***Keywords*—Virtual reality; road safety education; virtual scenarios; serious games; educational experience**

I. Introduction

Traffic education is a widely topic addressed worldwide but is not well understood. It refers to demographic elements, educational levels and even individual and collective identities. As it directly concerns road safety and the coexistence of actors, it requires a set of coresponsibilities in addition to the establishment, knowledge and socialization of rules of conduct among both pedestrians and drivers [1].

Currently, road safety education is considered a general problem whose responsibility falls to an entire society [2]. Its objective is increasing the awareness of citizens for the development of reasonable road behavior, but it is fundamentally responsible for the knowledge of the laws and regulations in force regarding public use and road safety. In this sense, road safety includes the absence of danger and risks from the existence of regulatory mechanisms in the context of traffic, which translate to the prevention of accidents [3].

Therefore, a traffic accident is an event generated in an unforeseen way that is beyond the control of the people involved, which can produce bodily, functional or organic injuries, leading to death or disability in the worst cases [4]. Since the end of the twentieth century, the Pan American Health Organization (PAHO) has shown that traffic accidents are among the main causes of injuries (serious or minor), disabilities and death in both developed and underdeveloped countries [5] [6]. Currently, they have become a kind of epidemic worldwide that has cost the lives of more than 1.24 million people—a public health problem for the World Health Organization (WHO) due to the high percentage of mortality among young people aged 15 to 29 years; indeed, by the year 2030, traffic accidents will be one of the five leading causes of death worldwide [5] [7].

In the context of Latin America and the Caribbean, the figures are alarming; even though the percentage of traffic accidents is well below that of developed countries, the rate of injuries and deaths due to road accidents is comparable to the levels in the United States and Canada. Specifically, countries with lower incomes have higher fatality rates in traffic accidents, 90 percent of which stand out as among pedestrians and cyclists, corresponding to the most underdeveloped countries. Hence, the PAHO has expressed the need not only for a continuous and systematic evaluation of road safety worldwide but also joint efforts involving different sectors of society to address road safety in a comprehensive manner through road safety education.

Ecuador is among the ten countries with the highest mortality rate in traffic accidents, despite being among the 5 countries on the continent with the lowest rate of registered vehicles [8]. Regarding the traffic accidents that occur daily in Ecuador, they are generally caused by citizens who take improper actions in their driving; pedestrians also regularly ignore current traffic and transportation laws, causing road accidents in which about half of the fatalities are pedestrians themselves [9]. On the other hand, the expansion of the means of transport for the mobilization of citizens in large masses has been a topic of high demand in most cities of Ecuador

due to the population growth that has been recorded in recent decades. In the city of Cuenca, the capital of the province of Azuay, located in the Andean highlands in the south of the country, which has been declared a Cultural Heritage of Humanity by UNESCO, the "*Tranvía 4 Ríos de Cuenca*" project has been carried out a public transport alternative. Its planning and construction began in 2012, and its commercial operation began on September 25, 2020 following a long and complex construction process, and many economic and technical problems that had been overcome [10].

Currently, the tram for the city of Cuenca is in full operation, and the contribution of this service has been noted to a large extent. However, there is a process requiring adaptation and education for mobility users to learn to coexist with this new means of transport. In addition to the accidents related to other means of internal transportation, there have been a variety of accidents involving this means of transport that have generated a notable increase in the accident rate [11]. According to an interview with officials at the *Empresa Pública Municipal de Movilidad, Tránsito y Transporte de Cuenca* (EMOV-EP), amid the increase in traffic accidents in the city, in recent years, multiple strategies have been created to increase the awareness of citizens of the rules and mechanisms for accident prevention [12]. However, these entail the necessary intervention of all agents and social sectors related to mobility, i.e., without excluding the academy as a fundamental element for intervening in this problem with research, all training proposals and road safety education strategies. Their purpose is to educate the public in the options for avoiding and preventing traffic accidents. All of their aspects should therefore be taken into account to reduce the high accident rates that have been shown in the previous research carried out by the authors of this scientific article [7].

Accordingly, the following question arises: How can a road safety education strategy, supported by information and communication technologies (ICTs), be developed to contribute to the improvement of the behavior of citizens to increase their proper use of traffic routes and thus reduce the number accidents?

To address this question, a joint work by the EMOV-EP, Universidad Politécnica Salesiana (UPS), and UPS's Cloud Computing, Smart Cities & High Performance Computing Research Group (GIPH4C), has proposed creating a Virtual Reality (VR) platform for sustainable road safety education in the city of Cuenca. The novelty of the proposal is mainly the possibility of reducing traffic accidents within the city through an educational technological platform that recreates environments similar to those of the city, providing an alternative with a novel approach to society that is completely different from previously developed VR platforms.

The use of VR as a learning technology allows the visualization of educational scenarios in all areas from a three-dimensional perspective. Computer-generated scenarios transform educational concepts via a new rapid sensory perception of individuals. The results obtained in the test phase of this project show a high index of motivation toward road safety education; users become the new protagonists for their own education, a fundamental requirement of the concept of gamification that has been introduced in the educational field of so-called Serious Games (SGs). Similarly, the potential of virtual reality is confirmed by the serious games perspective in the adaptive learning process and through its contribution to the development of a more responsible road culture through games [13].

From a theoretical point of view, the importance of the use of this technology is demonstrated by not only the interaction that a user has with it but also this technology's ability to activate all the human senses—especially touch, vision and hearing—whereby learning becomes more productive [14]. Hence, the proposal to use virtual reality technology for road training and awareness comprises a great milestone in the environment of road safety education.

Below, the main theoretical and empirical works related to the use of information and communication technologies for road safety education are presented. Next, we describe the development phases of the development of the virtual reality platform based on serious games for sustainable traffic education among mobility users in the city of Cuenca, Ecuador. In addition, the article presents the results from the test phase, which was carried out in conjunction with the EMOV-EP. Finally, we present the conclusions of the study and some recommendations for the platform's implementation.

II. Background

According to research at the *Universidad de Guayaquil*, since traffic accidents in Ecuador are one of the main causes of death in the population, especially among children and adolescents, road safety education should be considered a national problem that all social actors are directly responsible for [2]. Some of the main causes of traffic accidents are the recklessness of pedestrians and drivers, ignorance of current regulations, and so-called road complexity factors. Accordingly, the development of a virtual teaching-learning platform with 3D animation has been proposed as a strategy for increasing the awareness of citizens through education in road behavior rules. This proposal was initially limited to the training of high school students. Also, does not contemplate real spaces for the simulation of accidents, nor strategies of continuity and permanent implementation of the strategy. As for the techniques used for the development of the platform, it is not detailed in depth.

Similarly, the *Universidad Espiritu Santo* of Ecuador has proposed the development of an interactive T-Learning application [15] for road safety education. The platform is based on the ISDBT-Tb digital TV standards that allow the dissemination of road safety issues. Despite being a novel proposal for the education of road culture among citizens, its implementation as a strategy for reducing traffic accidents is based on the establishment of alliances between public and private television operators and educational institutions to provide generalized training throughout the country. This proposal is limited to the use of tools offered by the internet, which, although it has the capacity to generate changes in the behavior of citizens, does not offer the possibility of interacting face to face, and the research does not delve into the mechanisms for the update of the contents.

In correspondence with [3] the results of the study places Ecuador as one of the Latin American countries with the highest rate of traffic accidents. Among the causes of this

situation, the increase in the number of automobiles and the lack of knowledge about road safety by pedestrians and drivers stand out. Also, after analyzing the public policies and mechanisms established to reduce accident levels, the authors maintain that these have been ineffective because they focus mainly on the imposition of sanctions, without considering that the traffic accidents are a consequence of the lack of road education. In this sense, they warn about the need to overcome coercive policies. Despite the fact that the study assumed the city of Guayaquil as the field of action, the analysis of the results obtained after the application of theoretical and empirical methods allows the researchers to conclude that all of Ecuador requires educational programs based on accident prevention.

On the other hand, the *Instituto Tecnológico Bolivariano* in the city of Guayaquil, Ecuador, has proposed to use social marketing to increase the awareness of road safety among university technology students [16]. This research is a response to national statistics that show a lack of education in this area drives its accident rates and that young people are one of the groups with the greatest tendency to suffer irreparable consequences. According to this study, the main causes of road accidents are drivers' alcohol consumption, reckless actions, speeding, ignoring and disrespecting traffic signs and using cell phones. The proposed marketing strategy thus focuses on awareness-raising actions that are disseminated through social networks, cell phones and other personal channels to allow users to understand that road safety education is a way of life. The research establishes novel actions based on the promotion of road education, however, it is only aimed at technology students and does not present alternatives for the use of advanced information and communication technologies as part of the strategy.

This literature review of related works shows that most of the research and proposals from higher education institutions for the road training of citizens have been developed in the city of Guayaquil. However, statistical sources show that there has been a growing and accelerating accident rate in the city of Cuenca in recent years. The largest number of traffic accidents that occur in Cuenca are a consequence of the active or passive ignorance of the citizenry of the traffic and transportation laws and regulations that are in force in Ecuador. Such accidents are produced by the recklessness and speeding of drivers of light and heavy vehicles among other factors. Although in recent years higher fines have been established and a series of radar sites have been placed on both high- and low-speed roads with the purpose of warning citizens about the established speed limits, there is no evidence of a reduction in the number of accidents; on the contrary, they have increased. As a result, the city of Cuenca continues to experience a climate of road insecurity involving large numbers of accidents and deaths from various causes [17].

Notably, regarding the causes of road accidents in Cuenca, although Ecuador is not in the top 10 countries that consume the most liquor, driving under the influence of alcohol has become a highly recidivist factor in the city of Cuenca, causing countless traffic accidents; thus, the EMOV-EP considers alcohol consumption a necessary factor in its relevant analyses [18]. In addition to vehicle drivers, a fundamental component in road education and culture is obviously pedestrians, whose behavior directly affects the processes of the regularization of daily mobility. For example, it has been empirically observed that in areas of large agglomeration in the city, especially the most commercial and concurrent sectors such as the main markets [19], passers-by do not respect traffic signals at all, crossing through prohibited crossings such as pedestrian crossings and tram lines without being aware of the consequences that these actions may have for their physical well-being and that of the rest of the citizens who use public highways.

In addition, the city of Cuenca has a high rate of traffic accidents involving two-wheeled vehicles. The vast majority of these accidents are related to the lack of respect for traffic signs by cyclists, motorcyclists and/or pedestrians [20].This situation results in accidents that put people's lives at risk; due to their recurrence, a decline in road safety is generated that affects all citizens as well as the foreigners who throughout the year come to know and enjoy Cuenca. In this point it should be mentioned that, this capital of the province of Azuay in the Ecuadorian mountain range has been recognized by UNESCO as a cultural heritage of humanity due to its culture and the natural and architectural beauty that represent it.

Moreover, notably, according to the high figures from the EMOV-EP regarding the total accidents recorded in 2021, 24.97% were due to ignoring traffic signs, 21.11% were due to not paying attention to traffic, and 16.94% were due to driving under the influence of alcohol. These data coincide with the previously cited research. Collectively, such data show that in accidents where material losses are relatively high, injuries or human losses are also unfortunately present, thereby positioning this issue as of the utmost most importance—one that must be resolved in the medium and short term [7] .

Therefore, the EMOV-EP, as the body responsible for the regulation of human mobility in the city, in conjunction with the education system, promoted a series of road safety education campaigns to reach the greatest number of people in Cuenca's population. It thus allied with the *Universidad Politécnica Salesiana*, specifically with the research group GIPH4C, to create a greater number of frequent traffic drills throughout the city to involve the citizenship in these without people knowing that they have been drilled as such. However, due to its infeasibility, this option has been discarded; it was deemed economically in sustainable due to the numerous logistics involved. Specifically, it was found that emergency calls to 911 would cease to be important while the drill was implemented and thus the time allotted should not exceed 15 minutes to create spaces where citizens could intervene. Hence, such education implies assuming the costs that these drills represent and considering the logistics that all these processes entail; these are too high and numerous for the drills to be viable factors in producing the benefits that were the goals of this proposal.

Thus, based on an analysis of human mobility in the city of Cuenca and their joint discussion of alternatives for its regulation, the EMOV-EP and *Universidad Politécnica Salesiana*, through the research group GIPH4C, have proposed the following objective: to intervene through virtual reality technology via a virtual platform that allows creating environments similar to the environments of the city, creating the most appropriate alternative to try to resolve all the problems that have been discussed.

Furthermore, the antecedents analyzed in the first part of this research allow us to maintain that until now, the impact of platforms based on virtual reality on road training in Ecuador has been unknown. However, these new technological trends have been implemented in educational environments in general, such as virtual laboratories and learning based on serious games, with excellent results. The novelty of this proposal is thus the implementation of virtual reality technology with serious games in the field of road safety education to generate processes and new information and communication tools in regard to the road education of citizens in general [21].

That is, this paper entails the creation of a virtual reality system based on serious games for the training and awareness of citizens regarding aspects of road safety education.

Virtual reality is the simulation of a certain environment in which users are immersed and have the actual sensation of being there. Although its origins date to the 1960s, the costs of the equipment necessary for its operation have long been one of the main barriers to its distribution. However, the emergence of more affordable virtual reality hardware for games and entertainment has promoted a resurgence of virtual reality in recent years [22], sparking great interest in the field of education, especially concerning the imminent need to incorporate new technologies to improve teaching-learning processes [23] [24].

Thus, we analyze VR's properties of presence and immersion, which are considered key factors to strengthen learning. Presence allows the user to have the perception of being and existing in the virtual environment, while immersion entails the veracity that technology can evoke. However, for a true immersion of the user in the virtual environment, an additional factor is needed: interactivity. Since games are the most natural means for interactivity to be achieved, this is where SGs—those activities whose approach is innovative because they are designed for entertainment purposes but can also be used to educate or train users in certain areas—are salient [23] [25].

In the framework of this research project proposal, through the virtual platform, specific environments of the city of Cuenca are rendered in 3D within a virtual reality scenario to present the experience and various causes of a traffic accident to a user. The development of each scenario involves the use of virtual reality glasses with Oculus Rift/Quest technology [26] to overcome difficulties in the game while promoting learning through these experiences.

III. Methodology

The development of the project was structured into three stages based on the organization of serious games. The actions included in each of the stages are as follows:

1) **Living the Experience:** In this first stage, The player experiences a traffic accident in the first and/or third person, where emotions play a very important role. The idea is for people to reflect on what has happened. Thus, an introductory scenario is presented that allows them to understand the history of and know the causes that trigger the accident, generating greater awareness in each of the participants.
2) **Learning:** The accident that was experienced in the previous stage is repeated, but now a bank of questions is presented whenever a traffic violation occurs in the animation. At this stage, it is possible to measure the concentration of people while educating them about the violations presented. The responses to the questions are saved and then used to analyze the process later. To obtain a final score, a virtual driver's license is presented where a total of 30 points is accumulated. Each time a question is answered incorrectly, the score is reduced, depending on the violation committed. Thus, when the score is zero or the question bank segment has ended, feedback is presented on the questions that have been poorly answered.
3) **Free will:** In this stage, the player has the freedom to move around and interact with different objects that make up the virtual reality scenario without any restriction. The decisions that the players make during this stage experience, directly influence their final result. In theory, with the learning obtained in the previous stages, the participant at this time should make the appropriate decisions to avoid the same traffic accident in order not to repeat the game. Hence, the system successfully fosters their participation.
The "*Tranvía Cuatro Rios de Cuenca*" scenario has a more informative purpose than simply recreation or gaming *per se*. Therefore, in the third phase, the player has the possibility of approaching two different stops or tram stations, and overcoming various obstacles of daily life, such as pedestrian crossings, traffic signals, or traffic lights, with the aim of traveling to where a ticketing and ticket validation machine is located and interacting with it. Similarly, the players can recharge their balance and buy tickets for their subsequent boarding of the tram system. In this case, if a player commits an offense, a representative fine is given to train him or her in the proper use of the actual system by reducing inconveniences in its use. This is because the fine for not paying for this service has a current value of USD $ 120.00.

Notably, prior to the development of the three above mentioned stages, the identification of the places in the city, where the greatest number of problems arise was based on the agglomeration of pedestrians and traffic accidents. The sites with the highest recurrence were selected for the development of the virtual environments, as detailed in Table I:

TABLE I. Places Chosen for the Development of Virtual Environments

No.	Location	Problem found / Chosen scenario
1	Ave. *Huayna Capac* between *Calle Bolívar* and *Calle Larga*	Driving a vehicle under the influence of alcohol.
2	Ave. *Américas* entrance to *Quinta Chica* and *Hospital del Río*.	Driving vehicles at high speeds.
3	Ave. *Fray V. Solano* between *Los tres puentes* sector and *Virgen de Bronce* Church	Users of bicycles and cycle paths.
4	Ave. *Américas, Feria Libre - El Arenal* sector	Users of the tramway system.

Once the sectors to be displayed in the platform were selected, a photographic survey was performed. The use of the Street View tools of Google Maps and Sketchup allowed the development of all the 3D virtual scenarios. Subsequently, the information obtained was exported to the Unity 3D tool; by manipulating lighting, shadows and other factors, the desired images of the scenarios for the game experiences were obtained. Below, these images are presented in Fig. 1, 2, 3, and 4.

Fig. 1. *El Arenal* Virtual Scenario.

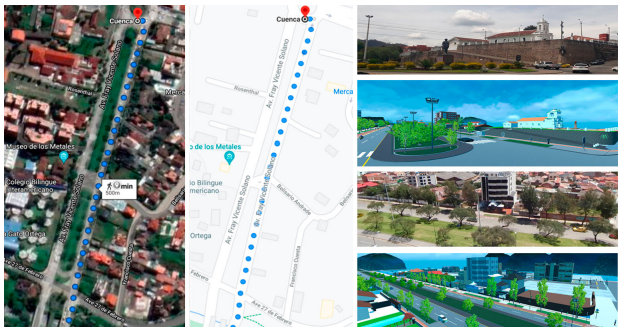

Fig. 2. *Los Tres Puentes* Sector and *Virgen de Bronce* Church Virtual Scenario.

Fig. 3. *Huayna Cápac* Avenue Scenario.

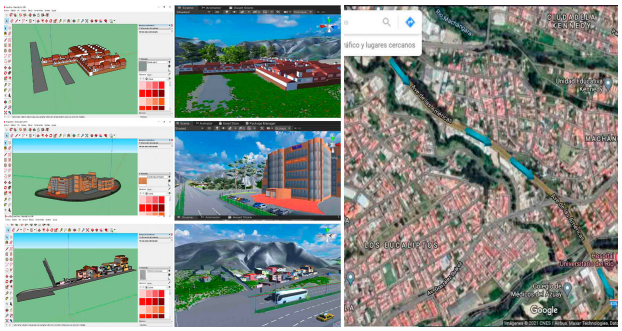

Fig. 4. Avenue of the *Americas* Scenario.

After developing the scenarios in a three-dimensional way with the tools described before, the next step was to establish all these places using Sketchup, Make Human, Adobe Fuze, Mixamo, and Blender, obtaining additional predesigned images from 3D Wearehouse. Humanoid characters and vehicles, which were positioned in various spaces within each scenario, were also created with their respective animations to approach the reality of each sector, as shown in Fig. 5, 6, and 7.

Fig. 5. Diversity of Vehicles Designed in the Local Context.

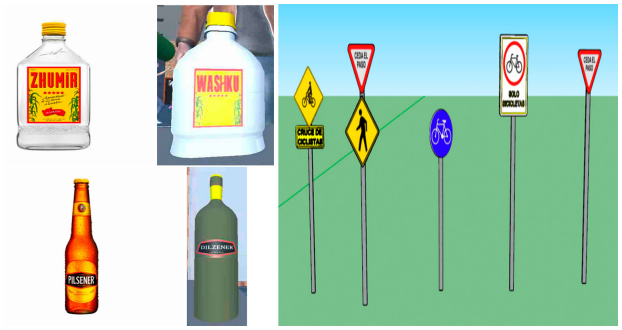

Fig. 6. Various Objects are Designed Similarly to the Originals.

An important factor throughout the research process and the development of the virtual reality proposal was the possibility of maintaining the effective representation of each place. Hence, common characters and vehicles to the city of Cuenca were included in the setting, such as the "*Cholita cuencana*" from Cuenca, a typical character of the city, visualized in Fig. 8.

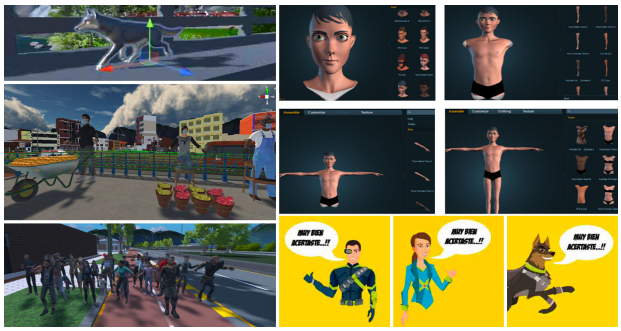

Fig. 7. Design of Varied Characters.

Fig. 8. Design of a "*Cholita Cuencana*" in 3D to be Included in the Scenarios.

To maintain the same criteria, street vendors were also included (see Fig. 9), as well as characters who are commonly found in different parts of the city and security personnel, such as police, citizen guards, traffic agents, and civilians.

Fig. 9. Design of Street Vendors in the City in 3D.

After creating these scenarios according to their local context, we designed a script in which the traffic accident that occurs in each sector is narrated, necessitating our investigation of the different accidents that usually occur in real life. This information was obtained from various local media, such as the *El Tiempo*[1], and *El Mercurio*[2] newspapers, the social networks of public security companies, such as *ECU-911*[3], and news websites. This information allowed us to determine the problems to be addressed in the scenarios and to identify the infractions that should be implemented in the context of serious games.

To better understand all the procedures that are carried out after traffic accidents and the reactions they generate among pedestrians and other security entities, the research team participated in drills conducted by the EMOV-EP during 2020. Through the observation of these drills, the different attitudes of people toward an accident involving a driver under the influence of alcohol and a cyclist on a cycle track were observed and recorded, as shown in Fig. 10. In this way, relevant conclusions were obtained to more realistically depict the specific scenario that we developed and presented.

Fig. 10. Simulation of Transit Accident Held in the City of Cuenca. *Where Members of the EMOV-EP and UPS Participate*.

Furthermore, the EMOV-EP constantly interacts with citizenship to transmit knowledge and education on road issues; these interactions became opportunities for the socialization of the research project (see Fig. 11). In these spaces, it was possible to present the serious game proposal to the public, interact with users and obtain useful feedback for the enrichment of the proposal and assure a better actual user experience, i.e., for users to effectively learn about the proper use of roads and the consequences of poor decision-making when driving a vehicle or traveling on the streets and avenues of the city.

Fig. 11. Socialization of the System with Citizens.

Another important component within the proposal concerns the mechanisms for evaluating learning among the platform's users. Therefore, a web platform has been developed. This platform allows the visualization of the reference question bank for each scenario and ensures that these are modified

[1]https://www.eltiempo.com.ec
[2]https://www.elmercurio.com.ec
[3]https://twitter.com/ecu911austro?lang=es

according to any needs or changes that occur, especially regarding cases of the application of fines.

In a complementary manner, the platform generates the data and statistics recorded by the entire system in graphical format. Through these data, it is possible to detect what questions are the most familiar to users and, in turn, the scenarios where the population has more difficulties or ignores more traffic laws (see Fig. 12 and 13).

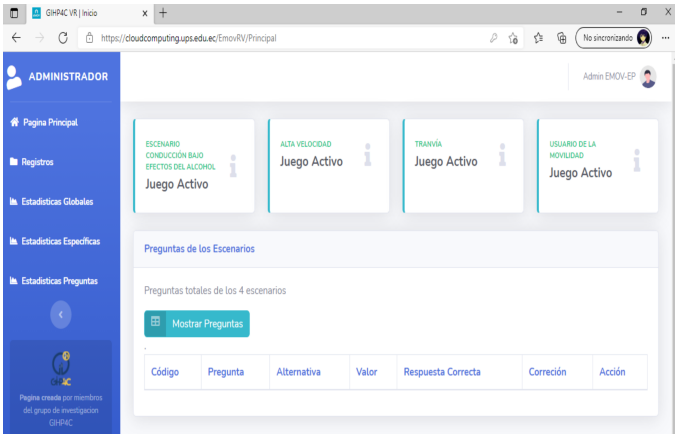

Fig. 12. Visualization of the Web Platform: Main Page.

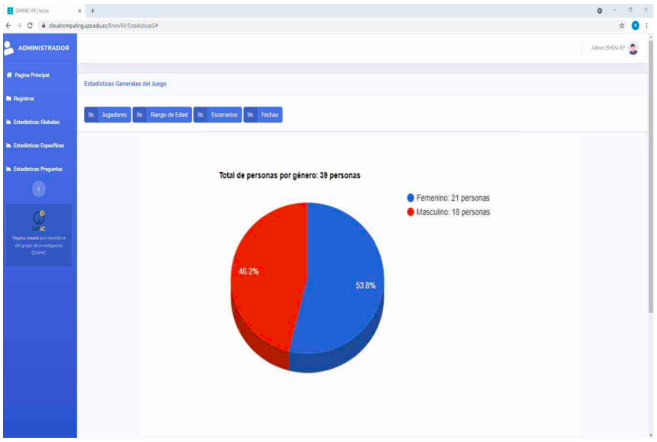

Fig. 13. Visualization of the Web Platform: Statistical Results.

Moreover, the storage system of the question bank is two MySQL databases, one local and one at the cloud level. Both databases maintain a master-master relationship. However, during the socialization of the project, it was observed that on some occasions, it is possible that there is no internet connection. Hence, the backup of the generated records must be stored on the local disk, but when there is a connection, they are uploaded to the cloud. To perform this procedure in the cloud, it is necessary to be connected to the internet through a static IP address that is assigned within the facilities of the EMOV-EP, guaranteeing the required information security.

IV. Results

A. Hardware and Software

To provide a greater understanding of the results of this project, developed jointly between the EMOV-EP, the *Universidad Politécnica Salesiana* and the UPS's GIPH4C research group, we provide the following basic characteristics of the necessary computer and the installation of the platform for use: computer with Windows 10 or higher operating system; video card Nvidia GTX1060/GTX 1660 or equivalent of AMD - Ryzen 2600/3600 or Intel i5 8600 or equivalent; Memory of 16 GB of DDR3 or DDR4 RAM; and, solid-state hard drive of at least 512 GB and a mechanical hard drive of at least 1 TB.

Nevertheless, in terms of performance and functionality, a certain latency has been observed in the fluidity and execution of the developed scenarios. Among the most important causes for this delay that we have detected are the following:

- **Lighting:** Lighting is an important factor when using many system resources since it visually depends on how much coloring and how many objects (including the addition of shadows) are added to each figure in the virtual scenarios.
- **Vertices and Groups of Objects and Rendering:** A surplus of groups and vertices to present very detailed objects causes the rendering to become slow when interpreting many points and details. It is thus advisable to make them more simple without too many details to improve the speeds of the processes.
- **Colliders:** It is better to generate these with fewer vertices and avoid their use; otherwise, it is necessary to include Mesh Colliders.
- **Occlusion:** How and when both objects and animations are visualized play a very important role in performance because they cause slowness and latency within the execution. It is advisable to use the parameter called Occlusion Map, since it gives different qualities in the rendering of the same object; the further away it is, the less its quality and thus fewer resources are used. In contrast, as you approach it, its quality and detail increase, using more resources in less time. This same parameter, due to the unified visual field of the camera, allows a rendering of a scene to be fixed as the viewer views it. Specifically, what the visual field of the camera captures is what is rendered and animated—such rendering and animation stops once the object or fraction of the scene with respect to the visual field of the scene is outside the camera's focus.
- **Scripts:** Script optimization is important for making the project work correctly because if there are infinite or constant loops, these will generate resource consumption.
- **Animations:** Within the animations, a factor to account for is the generation of the exoskeleton of the character to be animated. The greater the number of bones generated, the more fluid the animation will be and, in turn, the more graphic resources will be consumed. Hence, it is recommended that if a character does not perform movements that require complete control of all his or her joints, only a basic exoskeleton (control of head, neck, back and extremities) is rendered. Similarly, if the character does not

perform movements in terms of facial expressions, it is unnecessary to generate them, as these increase the weight of an animation due to unused resources.

Regarding the process of executing the scenarios in the computer, when executing the four scenarios at the same time, the consumption of video resources, RAM and cache memory of the computer is extensive; they are working at their maximum capacity, which causes an increase in hardware temperatures. In many cases, the programs can become "frozen"; therefore, they should be executed one scenario at a time, because a computer can only connect to a single Oculus device. By having only one scenario thus executed, everything functions without problems. A quick and timely solution, however, would be to expand the capacity of the computer's video card and RAM.

B. The Use of the System by Users

Due to the ongoing COVID-19 pandemic, declared worldwide by WHO [27] in late 2019, the socialization phase of the research project was reduced. However, given the obligation to understand the acceptance (or not) of the virtual platform by its end users, a group of 30 people was randomly chosen. The platform was presented to them and they experienced all four virtual scenarios. This entire validation process was carried out under strict biosafety measures. Once the presentation was completed, the group responded to a survey that was formulated to obtain feedback on the proposal via their comments and suggestions. Some of the most important questions and its answers of the survey are presented in Table II, which concern the user's level of knowledge generated by a traffic accident scenario, perception of virtual reality, identification of the sector of the city and evaluation of the experience of learning through play.

It is important to note at this point that the limitations presented in the validation phase of the proposal did not affect the process of verifying the usefulness and operation of the platform. Indeed, the answers to the questions for all four scenarios were favorable. As shown in Table II, an average of more than 60 percent of the people surveyed rated them with the highest score. Notably, moreover, the contributions, observations and suggestions from those who interacted with the platform, in addition to the recommendations of the specialized staff at the EMOV-EP, will be considered in the construction of the next stages of improvement and implementation of the virtual platform project.

V. Discussion

The literature review on the use of information and communication technologies to promote road education, previously detailed shows on one hand a growing concern about the accelerated increase in the rate of traffic accidents in Ecuador. On the other hand, it is also notorious the emergence of proposals from higher education institutions in order to promote actions that lead to the training of citizens in terms of knowledge, respect, and compliance with current laws and regulations on the matter.

Therefore, in the following paragraphs, we discuss the meeting points and differences between this proposed and the main related works addressed.

Research work in [1] contributes to our paper from the theoretical point of view which exposes the aspects related to road education, its relationship with road safety, and the necessary participation of the different actors of society; in the generation of articulated actions, from the roles and responsibilities of each instance. As for the work proposal mentioned above, it is restricted to the exposition of government actions implemented in Guadalajara-Mexico for the education of adults in respect of traffic laws. As a result, the authors proposes the implementation of a road education subject as an elective course at the *Universidad de Jalisco*. Finally, the work does not detail in depth the methodology used to generate the proposals. Likewise, it is limited to adult education, which greatly differentiates it from the proposal for the use of serious games in our research, which can be aimed at children, youth, and adults.

In the local context, another similar study is presented by [2], which concur with the gathering of its empirical information and the results of our paper regarding to the high accident rate in several cities of Ecuador. However, the study is limited to the city of Guayaquil. Similarly, our research coincides with the consideration of road education in Ecuador as a national problem, which makes it necessary to generate joint and multidisciplinary actions to reduce what they define as a technological scourge. Regarding the methodology, they are based on a training process through interactive websites with 3D animations but are only aimed at young high school students. Last, the study does not expose the methodology for the development of the applications used. Nor does it detail the results obtained in the implementation of the proposal.

In the same way, the authors in [3] agree with our study regarding the approach of traffic accidents in Ecuador as a public health problem, due to their accelerated growth in the last two years. However, among the causes of this growth, the authors point out the lack of government commitment to complement effective politics in the mobility area. Whereas, in our proposal, we have recognized mechanisms for road education in the city of Cuenca in which we have involved public and private, social, academic, and governmental actors. Also, the analyzed research is limited to proposing the development of road safety educational projects in the field of educational institutions. However, the components of the training or techniques and instruments for its application are not exposed. As result, the identification of accident statistics in the city of Guayaquil stands out, in addition to the characterization of the training undertaken by the educational units in road education.

Moreover, the authors in [16], address the city of Guayaquil as a field of action and they have the same point of view as previous and our investigations in considering that traffic accidents constitute one of the main causes of death in Ecuador, mainly for young people. Another point of agreement between the investigations has to do with affirming that the lack of road education is a fundamental factor in accident rates. In relation to the research proposal, revolves around marketing strategies and is addressed only to students of Technological Institutes. In the results, the research coincides with the data obtained in our paper by pointing out recklessness, disrespect for traffic signs, alcohol consumption, and the use of cell phones while driving as causes of main accidents.

TABLE II. COMMON QUESTIONS AN ITS ANSWERS FOR EACH SCENARIO USED FOR THE VALIDATION AND ACCEPTANCE OF THE PROJECT

Scenarios	**Questions**				
	Question 1 *How much did you correctly appreciate and understand the theme of the accident presented in each scenario? On a range from 1 to 3, where 1 is Nothing and 3 is Everything.*				
	Option 1		Option 2		Option 3
Driving a vehicle under the influence of alcohol	**0**		**0**		**30**
Driving vehicles at high speeds	**0**		**0**		**30**
Users of bicycles and cycle paths	**1**		**3**		**26**
Users of the tramway system	**0**		**8**		**22**
	Question 2 *How did you find the Virtual Reality experience? On a range from 1 to 5 (1 as very bad and 5 as very good)*				
	Option 1	Option 2	Option 3	Option 4	Option 5
Driving a vehicle under the influence of alcohol	**0**	**0**	**1**	**7**	**22**
Driving vehicles at high speeds	**0**	**0**	**1**	**4**	**25**
Users of bicycles and cycle paths	**0**	**0**	**7**	**10**	**13**
Users of the tramway system	**0**	**0**	**6**	**9**	**15**
	Question 3 *Were you able to identify the sector of the city where you were?*				
	Option Yes			Option No	
Driving a vehicle under the influence of alcohol	**29**			**1**	
Driving vehicles at high speeds	**29**			**1**	
Users of bicycles and cycle paths	**22**			**8**	
Users of the tramway system	**22**			**8**	
	Question 4 *How would you rate the experience of playing and learning through these virtual means? On a range from 1 to 5 (1 as very bad and 5 as very good)*				
	Option 1	Option 2	Option 3	Option 4	Option 5
Driving a vehicle under the influence of alcohol	**0**	**0**	**0**	**3**	**27**
Driving vehicles at high speeds	**0**	**0**	**0**	**2**	**28**
Users of bicycles and cycle paths	**0**	**0**	**3**	**6**	**21**
Users of the tramway system	**0**	**0**	**0**	**7**	**23**

VI. CONCLUSION

The use of ICTs to promote road education in Ecuador evidences the development of several research papers in which traffic accidents and their consequences are considered a public health problem that cannot be addressed only by establishing public policies, but with the cooperation of different sectors of society (public and private). The research papers studied are limited to the analysis of the causes and not the presentation of innovative proposals that go beyond the traditional methods of training in road culture. Similarly, the bibliographic review found a diversity of research applied in Ecuador, however, most are developed in the context of the city of Guayaquil, and for the city of Cuenca, there is no evidence of research proposals of great impact for reduce the number of accidents through road education.

The development of road education proposals based on virtual reality with a focus on serious games is currently a highly relevant topic. Through our review of the theoretical and empirical background of this research, it is evident that first, traffic accidents have become one of the main causes of death not only in Ecuador but also globally. Second, the growing number of accidents in the city of Cuenca, Ecuador is mainly generated by high speed, driving under the influence of alcohol, recklessness of drivers and pedestrians, and ignorance of traffic rules and signals. Accordingly, the need to articulate interinstitutional efforts is evident, a prerequisite to generating proposals that mediated by new information and communication technology, can contribute to the formation of a road culture in the city of Cuenca.

The social impact of the project developed jointly by the EMOV-EP and the GIPH4C, made up of professor-researchers from *Universidad Politécnica Salesiana*, derives from the creation of a 3D virtual platform based on entertainment through the simulation of environments. Its purpose is to train, educate and raise awareness among citizens about the proper use of roads for the prevention of the traffic accidents that according to official statistics typically result in irremediable situations. Hence, it is proposed that through the use of new technologies for learning and the serious games approach, citizens will understand and learn about traffic education in the city of Cuenca.

For the structuring of this 3D virtual platform of traffic education, the sites in the city of Cuenca where there is a greater occurrence of accidents due to pedestrian agglomerations or traffic incidents were identified. In each of these scenarios, the various situations that lead to accidents or fines for failing to comply with traffic regulations were simulated. The virtual environments also included the "*Tranvía Cuatro Rios de Cuenca*", a means of mass transportation that has been operational since 2020. Given the novelty of the service it provides, citizens remain unaware of the rules for its proper use and do not grasp that the failure to comply with them carries fines and other penalties.

The validation of the virtual platform for road safety education with an Social Group focus was carried out through tests performed on citizens. A group of 30 randomly selected people experienced the 4 virtual environments, witnessing common situations related to mobility within the city. Once their simulation was complete, these users of the platform answered a series of questions about its operation, composition and usefulness. The results of the survey show that 91 percent of people fully understood the context presented in each scenario. After the survey, the personnel in charge of the EMOV-EP asked a question about road safety that was addressed in the

scenarios presented and obtained 100 percent correct answers. Thus, this project clearly has great educational, technological and innovation potential; it can therefore be implemented as an education and road awareness strategy in the city of Cuenca.

The results obtained in this first phase of the project are considered theoretical and empirical background for the continuity of this and other research that aims to promote road culture through the use of immersive technology as an education tool.

REFERENCES

[1] C. M. Pacheco Cortés, "Educación vial en la era digital: cultura vial y educación permanente," *Diálogos sobre educación. Temas actuales en investigación educativa*, vol. 8, no. 15, 2017.

[2] J. E. Fernández Escobar, A. M. Ávila Portuondo, and R. Milanés Gómez, "La educación vial asistida por tecnología 3d: un modelo de su enseñanza-aprendizaje," *Revista Universidad y Sociedad*, vol. 9, no. 3, pp. 130–134, 2017.

[3] D. C. Anchaluiza Iza and A. L. Sellan Naula, "Accidentes de tránsito como consecuencia de la falta de educación vial en la ciudad de guayaquil," B.S. thesis, Universidad de Guayaquil, Facultad de Jurisprudencia Ciencias Sociales y Políticas, 2020.

[4] M. E. Salinas Cabrera and L. H. Vele Figueroa, "Estudio científico de la accidentalidad de tránsito en el cantón cuenca," 2014.

[5] O. P. de la Salud, "Los accidentes de tránsito son la primera cauda de mundial de muerte entre jóvenes de 15 a 29 años, 2013," 2013.

[6] W. H. Organization, "Informe sobre la situacion mundial de la seguridad vial : es hora de pasar a la accion," p. 287 p., 2009.

[7] G. A. León-Paredes, O. G. Bravo-Quezada, E. J. Sacoto-Cabrera, O. F. Pizarro-Gordillo, P. E. Vintimilla-Tapia, J. F. Bravo-Torres, and W. P. Cabrera-Chica, "Virtual reality and data analysis based platform for urban mobility awareness as a tool for road education," in *2020 IEEE ANDESCON*. IEEE, 2020, pp. 1–6.

[8] O. P. de la Salud and O. M. de la Salud, "La seguridad vial en la región de las americas," 2016.

[9] J. L. Rivas Luna and D. Santos Rodríguez, "Factores de riesgo que inciden en los accidentes de tránsito en el ecuador," 2019.

[10] S. Rumé, "Sobre imposiciones y adecuaciones infraestructurales. el caso del tranvía en cuenca, ecuador," Master's thesis, 2018.

[11] C. T. de Cuenca. (2021) Camión causa daños en la ruta del tranvía de cuenca. [Online]. Available: http://tranvia.cuenca.gob.ec/content/cami{\'o}n-causa-da{\~n}os-en-ruta-del-tranv{\'i}a-de-cuenca

[12] J. D. Arévalo Peña, "La eficacia publicitaria en las campañas de prevención en seguridad vial," Master's thesis, Universidad del Azuay, 2016.

[13] E. R. Escartín, "La realidad virtual, una tecnología educativa a nuestro alcance," *Pixel-Bit. Revista de Medios y Educación, 15, 5-21.*, 2000.

[14] E. C. Andrade Andrade and E. J. Velázquez Guerrero, "La biblioteca de la facultad de ingeniería en la plataforma educativa de la udelar-uruguay: implementando un servicio de formación de usuarios virtual," *Revista Interamericana de Bibliotecología*, vol. 37, no. 2, pp. 171–178, 2014.

[15] S. Encalada Chérrez and I. Silva Feraud, "Aplicativo t-learning para tdt en el ecuador," *Investigatio Research Review*, no. 6, pp. 67–80, 2021.

[16] M. S. Tolozano Lapierre, "Marketing social para promover la seguridad vial en estudiantes de institutos tecnológicos, caso: Instituto superior tecnológico bolivariano-guayaquil 2019." Ph.D. dissertation, 2018.

[17] G. R. Zambrano and V. E. Senti, "Marco de trabajo para el diseño de una arquitectura its en ecuador que mejore la interoperabilidad y el despliegue de los sistemas de control de tráfico vehicular/[framework for designing an its architecture in ecuador that improves the interoperability and deployment of vehicular traffic control systems]," *International Journal of Innovation and Applied Studies*, vol. 14, no. 4, p. 886, 2016.

[18] C. L. C. Morocho, "Análisis de la percepción que tienen los infractores de tránsito sobre conducir en estado de embriaguez en la ciudad de cuenca," Ph.D. dissertation, Universidad De Cuenca, 2016.

[19] A. Cárdenas-Rebelo and J. A. Orozco-Toro, "Publicidad social y su influencia en la percepción de las campañas sociales de prevención de accidentes de tránsito en ecuador," *RETOS. Revista de Ciencias de la Administración y Economía*, vol. 10, no. 20, pp. 219–231, 2020.

[20] P. A. Chimbo Cárdenas and C. S. Jadán Loja, "Determinación de los factores de riesgo en accidentes de tránsito donde están involucrados vehículos de la categoría l en la ciudad de cuenca," B.S. thesis, 2017.

[21] I. Aznar Díaz, J. M. Trujillo Torres, and J. M. Romero Rodríguez, "Estudio bibliométrico sobre la realidad virtual aplicada a la neurorrehabilitación y su influencia en la literatura científica," *Revista Cubana de Información en Ciencias de la Salud*, vol. 29, no. 2, pp. 0–0, 2018.

[22] I. Wohlgenannt, A. Simons, and S. Stieglitz, "Virtual reality," *Business & Information Systems Engineering*, vol. 62, no. 5, pp. 455–461, 2020.

[23] D. Checa and A. Bustillo, "A review of immersive virtual reality serious games to enhance learning and training," *Multimedia Tools and Applications*, vol. 79, no. 9, pp. 5501–5527, 2020.

[24] G. Mariscal, E. Jiménez, M. D. Vivas-Urias, S. Redondo-Duarte, and S. Moreno-Pérez, "Aprendizaje basado en simulación con realidad virtual," *Education in the Knowledge Society (EKS)*, vol. 21, pp. 15–15, 2020.

[25] Z. Feng, V. A. González, R. Amor, R. Lovreglio, and G. Cabrera-Guerrero, "Immersive virtual reality serious games for evacuation training and research: A systematic literature review," *Computers & Education*, vol. 127, pp. 252–266, 2018.

[26] C. Hillmann, "Comparing the gear vr, oculus go, and oculus quest," in *Unreal for Mobile and Standalone VR*. Springer, 2019, pp. 141–167.

[27] W. H. Organization *et al.*, "Brote de enfermedad por coronavirus (covid-19)," *Recuperado de https://www. who. int/emergencies/diseases/novel-coronavirus-2019*, 2020.