Systematic literature review to explore use of VR in transportation research to study driver behavior

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Abstract

This paper presents a survey on Virtual Reality (VR) immersion in the Intelligent Transportation System (ITS). The semantic meaning of training in virtual reality includes the analysis of functions and structure of a virtual system. Driver Assistance System (DAS) takes the three-dimensional input using radar and vision systems to assist drivers in driving activities. These systems are not only used to identify the key challenges of building an adaptive virtual environment but also to make the virtual driving training and urban planning possible and effective. There is a lack in understanding VR effectiveness, exposure of VR to the human psyche, and the efficient outcomes of using VR for training purposes. Currently, the focus of research is on the concept of presence but this paper gives an advanced review in the multifaceted field. It starts with the customary theory of reality and merges it with virtual reality. The relationship between driver training, urban development, and treatment of driving phobias results in an intelligent Driver Training System (DTS). DTS gives the missing key benefit for the full control of another dimension Knowledge of these relevant factors can play a vital role in the development of new VR applications for DTS. In this paper, we will discuss three key characteristics which are an assessment, the involvement of users, and efficiency of results produced to evaluate factors affecting driver's performance, transportation planning and treatment of phobic patients. In this paper literature from 1975 to 2025 is evaluated.

Keywords: Intelligent Transportation System (ITS); Urban Development; Driver Training Systems (DTS); Virtual Reality (VR); Psychological Problems; Driver Behavior, Driver Safety Assistance; Transportation Planning; Virtual Intelligent Vehicle (VIV); Driver Assistance System (DAS).

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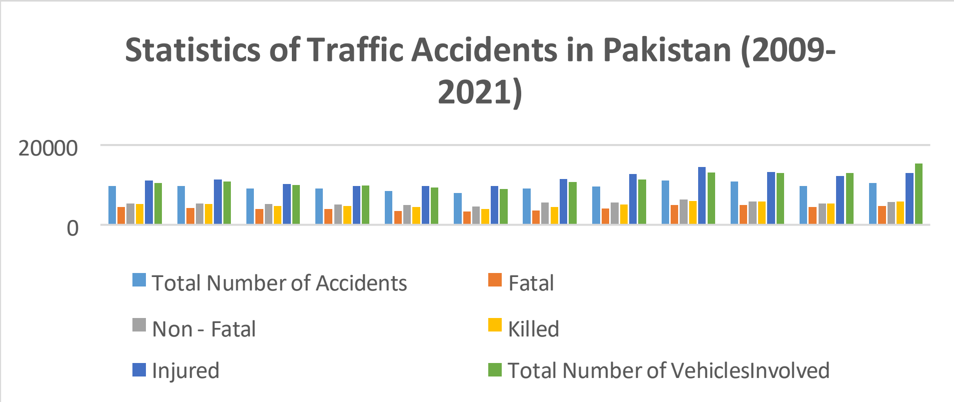
Introduction

The ever-increasing need for transportability has brought an enormous number of vehicles on the roads [1]. Populating roads with a rapidly increasing number of vehicles has caused inefficiencies [2]. Inadequacies in infrastructure, higher mobility rate, inexperience, driver behavior, urban development and psychological problems affect the performance of the driver. It is believed that these are the main causes of the higher accident rate in larger cities [3]. Thousands of traffic accidents occur every year, causing numerous casualties and tremendous economic loss in Pakistan as shown in Fig. 1., as mentioned in a report by the Pakistan Bureau of Statistics. These accidents are increasing as the traffic mass is increasing with the years. Intelligent Transportation System (ITS) could be employed to reduce the inadequacies of the current transportation system. ITS focuses on driver training and assessment, the design of an efficient road network to ensure safety and restoration of infrastructure so that effective mobility could be made possible [4], [5], [6]. Driver training system, driver assistance system and virtual intelligent vehicles are steps towards the Intelligent Transportation System. An approach is required to obtain adaptability of new traffic circumstances, providing assistance and to address situational complexity, therefore a more humanistic transportation solution shall be provided.

This can be apprehended by introducing ITS for the management of urban development [7], [8], driver training [9], and assessment [10]. Furthermore, medical treatment can be provided using VR-based simulators to drivers with psychological [11] and physical disabilities [12]. This report presents a systematic review of the use of Virtual Reality (VR) in developing ITS. VR is a computer-generated 3-dimensional environment, where interaction can be done using sensors like a Head-mounted display (HMD) or haptic feedback gloves. VR systems are currently used in multiple fields, such as in the medical field, different simulation-based systems have been developed for the surgical training, rehabilitation, and therapy of phobic people. VR-based rehabilitation and therapy systems allow doctors to present patients with scenarios that they have difficulty facing and imagining.

Similarly, the adoption of VR in transportation research is very important as it helps to counter various traffic-related risks and safety issues [13], [14], [15]. The survey will specifically focus on major components of ITS such as design and analysis of road infrastructure, tools for driver training and assessment, and tools for driving phobia treatment

Figure 1: *Statistics of Traffic Accidents in Pakistan*



Literature Review

Over the past two decades, ITS has been established and organized to improve transportation safety, driver performance, and mobility [16], [17]. Drivers' performance plays a vital role in ITS because the dynamicity and adaptability of road infrastructure are dependent on it. Better infrastructure would not matter if the driver drives hazardously which results in accidents [18]. Furthermore, due to the careless behavior of the driver the adaptability and mobility of traffic declines. Novice drivers can be trained in virtual reality to enhance their skill set, which will increase their performance and consequently adaptability of the whole system [19]. Similarly, computer-aided driver training could be used to help physically [12] and psychologically [11] challenged drivers. Another issue is an ever-increasing number of vehicles which put a strain on existing road infrastructure.

To enhance the capability of existing infrastructure and to introduce new infrastructure, tools are required to analyze different scenarios on existing road infrastructure [20]. Computational tools could be used by urban planners and transport managers for modifying and enhancing road infrastructure [21], [22].

VR powered immersive technology can be used to develop systems that would contribute to developing ITS [23]. This study has been performed to analyze state-of-the-art literature and technology, which could be employed for the sustainability of the road infrastructure and to improve the driving characteristics of individuals. The purpose of performing this research is to identify how the evolution of VR to study driver behavior has impacted the ITS. Furthermore, this research is performed to identify the statistics of various impacts such as health conditions, driver behavior, and gender. Articles are included after reading titles and abstracts to induce correlation with the research objective. Importance of VR in transportation

A systematic literature review is important for exploring the use of virtual reality in transportation because this can help to develop cognitively-intelligent transportation system. The systems developed till now can be categorized in three categories: (i) urban development [20], (ii) driver training for skill set enhancement [6], and (iii) treatment of phobias related to driving [11]. Driving simulations play an important role in driver training and assessment [13], [24], [25].

Prior to construction, the road networks can be analyzed through virtual simulations based on traffic flows and congestion [26], [27], [28], [29]. The virtual simulations can help to generate data regarding driver behaviors, which can be used in developing an advanced driver aid system (ADAS) for assisting the driver during real-life driving [30], [31], [32], [33], [34]. Thus, the VR-based driving environments and experimentations can help to tackle and evaluate various safety risks and traffic issues, efficiently. An intelligent transportation system (ITS) needs to be designed to achieve efficiency by incorporating the above three aspects in combination. Because these three aspects are dependent on each other to sustain transportability [35].

Therefore, by overlooking one and addressing the other will reduce the effectiveness and numerous situations will be ignored. For example, if road infrastructure is well designed but the driver, while driving, stays low on performance due to long tunnel or high-speed phobias, it will affect the feasibility of the road infrastructure. In this example, there is a high dependency between urban development and the performance of the driver.

Research area of ITS will remain incomplete if the factor of a realistic approach for implementing ITS in virtual reality (VR) is ignored [36], [37], [38]. Here realistic approach refers to the implementation of ITS in VR considering the real-life scenarios and uncertain situations. Immersion in VR will robust the tool for driver training and computational modelling of adaptive urban development [39], [40]. The Figure 2 depicts an overview of the evolution of VR applications in transportation research from 1975 to 2025. In diagram we can see how role of VR in studying driver behavior has evolved in transportation research.

Figure 2: *Overview of the evolution of VR applications in transportation research*

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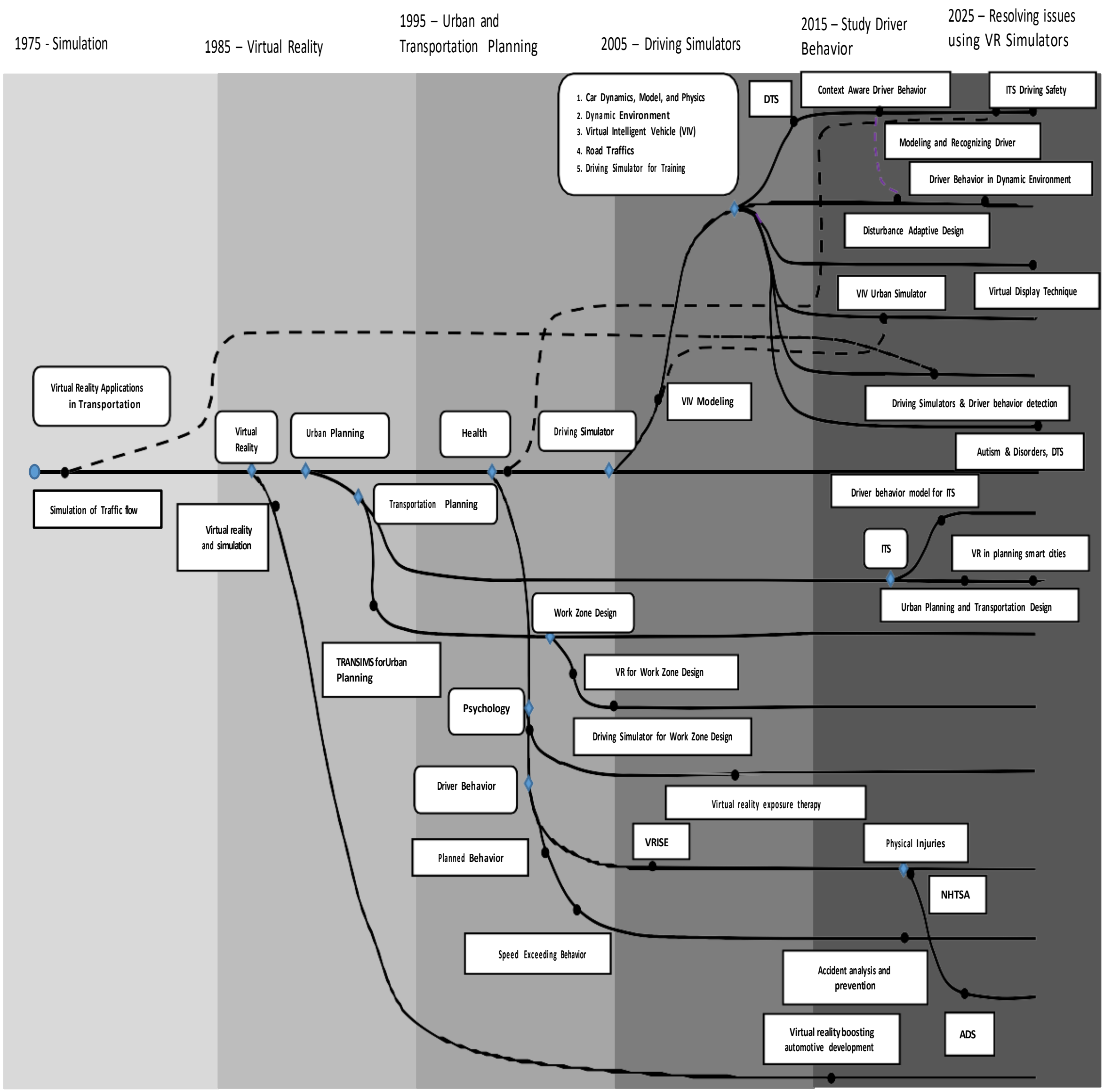


Taxonomy

In reviewing the literature on the use of virtual reality in transportation research, the studies can be grouped into a clear taxonomy based on their focus and methodology. The first layer distinguishes VR technology types, including head-mounted displays, CAVE environments, and desktop simulations. Within these, the research is further divided by the driver behavior aspects studied, such as cognitive decision-making, visual perception, and motor responses. Another branch classifies the work according to transportation contexts, for example, passenger vehicles, freight systems, or mixed traffic scenarios. Finally, the studies can also be grouped by methodological approach, including controlled experiments, simulator-based evaluations, and field trials. This classification helps to make sense of a diverse body of work and provides a structured basis for comparing results across different subfields.

Discussion

The realistic approach is an important school of thought in developing ITS using VR. This approach for implementing ITS in VR comprises a list of features. Some general features, which will assist user realistically [41], [42], [43], are explained in this section.

Driving Simulator

Traditionally, driving simulation models have been used to train drivers to adapt to traffic layouts, rules, and behaviors [19], [44]. During the last decade, there has been a growing interest in designing driving simulators to train and instruct drivers [45], [46], [47]. Later psychologists and physicists have been paying special consideration to the driver training using simulators [43], [48]. Because the mobility depends upon many characteristics as it is basically a result of driver behavior and stimulus from the external dynamic environment. Furthermore, the driver's behavior is influenced by the dynamics and physics of the vehicle [18], [49]. Psyche and physique of a driver interpret his behavior with respect to the stimulus generated from internal (previous experience) or external environment (rain, light intensity, accidents etc) [50]. Previous experiences reshape the behavior of a driver with respect to the external stimulus generated from the predictable or unpredictable environment. Driver models could be designed on the basis of generic driver behaviors. In some recent studies, different types of simulators have been proposed involving the dynamics of traffic, pedestrians and other kinds of vehicles [51], [52], [53], [54]. VR pedestrian training simulator is designed to educate and train children to safely cross intersections for injury prevention [55], [56]. These simulators aid in performing cost-effective and safe experiments related to transportation research and the models developed based on these experiments can be used to develop realistic traffic simulations [57], [58], [59].

1. Car Dynamics, Model, and Physics

Driving simulators play a significant role in development of a autonomous vehicle where human factors and driver assistance systems are primarily concerned [60], [61], [62]. Because factors such as a vehicle's body dynamics play a very sensitive role, driving simulator activities must be similar to the reality [63], [64], [65]. simulation-based experiments can be carried out in close proximity to actual driving conditions, which can produce precise results [49]. A vehicle's dynamics model affects a driver's perception to a greater extent [66], [67]. Vehicle Dynamics Model (VDM) of a VR Driver Training System (DTS) calculates the physics and maneuverability of a real vehicle, where calculations are performed with respect to the environmental circumstances and the inputs being provided. A model can be proposed for calculating the movement of near-side vehicles when driving in the usual environment, demonstrating real vehicle behavior on the roads. [68]. DTS is a training system that trains and tests a novice driver to improve driving skills [69]. Various DTS of this kind have been proposed recently [69], [70], [71]. Furthermore, the traffic simulation models also present realistic and probable behavior in some oppressive driving conditions such as maneuverability while avoiding a collision. Model validation is another important part to make sure that the VDM behaves like a real vehicle [72], [73], [74]. In addition, the VDM can be trained to analyze the assessment data when executing the predefined manoeuvres [75]. At last, the VDM validation is performed consisting of DTS experiments where diversely skilled drivers are evaluated against the new VDM to assess the behavior of the new model [76], [77]. Modern vehicles contain mechatronic components to provide ease to the drivers. Mechatronics components such as Anti-Lock Braking System (ABS), an electronic stability program (ESP) and Predictive Advanced Front Lightning System (P-AFS) provides safety to the driver. P-AFS is used in the VR based night drive simulator in which the effects of vehicle dynamics on the lighting can be assessed [78].

2. Dynamic Environment

In virtual reality, 3D environment designing introduces noticeable challenges for simulator development. Most of the VR based systems are based on monolithic architecture (architecture with the static environment), that affects the usability of a system [79], [80], [81]. To make an environment more realistic, various factors such as weather, lighting conditions, terrains, and other environmental aspects are incorporated into a VR based environment [58], [71], [82], [83], [84]. When there is a new model or notion that requires implementation of a new function such as lighting conditions, it becomes impossible to extend or replace that novel functionality. Key problem in the existing development trend of VR simulators is that it results in advancements with minute evolvement. To resolve this dynamicity problem, there is a need for an Adaptive Dynamic Environment to develop VR simulators for achieving better and precise results while performing experiments. Such environments and their adaptability are presented in some recent studies [85], [86]. sometimes various issues related to environmental dynamics include immersion of the trainee in VE and the association of VR simulator reliability. Driving simulator performance cannot impact the context-specific environment. Avoidance of a key feature (dynamic environment) implementation in simulator will badly affect the performance of a novice driver (trained on that simulator) on road. To achieve realism in the driving simulator, HDS cluster system, is used which generates a scenario that is highly immersive. It is achieved by running the driving simulator based on PC clusters [87]. Furthermore, the implementation of dynamic environment feature in driving simulator will result in an economic and pedagogical advantage [88].

3. Virtual Intelligent Vehicle (VIV)

The intelligent driving behavior of the VIV in the driving simulation system is fundamental to achieve realism and reliability of the simulator [89], [90]. Such depiction of intelligent vehicles is already reported in some recent studies [91], [92]. Experimenting with different algorithms in VR training systems is an essential step while equipping upcoming simulators with intelligent capabilities. This step is sometimes difficult to perform, particularly, due to technological complications such as hardware capability or time requirement of an algorithm [93], [94], [95]. Sometimes it is challenging to emulate the same situation or setup, repeatedly. Moreover, some intense or acute circumstances cannot be experimented in real life. VIV retrieves the information from the surrounding environment with high efficiency to accomplish the decision-making process required to generate a response in the form of manoeuvres for stimulus using VR driving simulators. This stimulus depends on internal (Previous experience) and external environment (rain, light intensity, accidents, traffic flow etc). Therefore, the evaluation of algorithms implemented in cars, using the same experimental setup (an environment is required repetitively for performing experiment) with simulation tools to assess driver performance in situations, will be near to reality. Superscape VR based simulator is designed which collects data from the surrounding environment using virtual sensors and then manipulates the manoeuvres of a controlled vehicle to keep safe distance [96].

4. Road Traffic

Road transportation is a motion of the vehicle to transport people and goods from a place to its destination through road networks [5]. Road networks with congested traffic flow, unpredictable driver behavior and dynamic scenarios create a problem [97]. Traffic flow is categorized by many problematic features that shape it such as congestion [98] It is hard to be analyzed and to infer for providing an optimized solution. Microscopic traffic models identify the behavior of the traffic flow and the interaction of traffic within. Microscopic models of traffic simulate single driver vehicle systems, these models reflect microscopic properties of a vehicle, such as single-vehicle position and velocity. However, in a few recent studies, the flow of microscopic traffic and optimization of traffic flow has been studied [14], [15]. Furthermore, traffic flows are inherently dynamic in nature [97]. Dynamic traffic flow is defined as the number of vehicles on the road that varies with respect to time, and with a substantial amount of unpredictable driver behavior according to the environment. The massive number of vehicles at the same time on the road means an excessive number of instantaneous interactions. Therefore, traffic road simulator with previously designed traffic models has the capacity to evolve. It will enable one to study the impact of congested traffic flow, the road network and driver behavior on traffic fluency. In DTS, the traffic generation module will center on a system with multiple vehicles in which each vehicle is an entity with autonomous behavior. This will provide a reliable road traffic simulation solution that will be used for experimenting with a road network [98]. Physicists are currently working on the physics of traffic flow. Vehicle movement is a result of driver manoeuvres that has many characteristics. These manoeuvres depend upon the driver behavior and stimulus generated from external environment [101]. AReViRoad is VR based simulator that helps in determining the impact of the road network on traffic fluidity [102], [103]. Traffic flows can be modelled and simulated using advanced technologies for performance assessment to determine the flaws in transportation planning [104], [105] that will make transportation intelligent, by eliminating problems such as congestion [106], [107].

5. Driving Simulator for Training

The word “driving simulator” was initially used for the hardware equipped with the software used to measure the driver behavior in virtual reality [108]. In the early stages, simulators were used for research in vehicle industries and research labs to study driver behavior. But now the term “driving simulator” is used for driver training to improve driving skills, psychological phobias related to driving or for issuance of driver’s license [109]. Realistic car driving also necessitates the driver to look in surrounding because visual attention is an important measure of good driving [110]. The driving simulator has three main perspectives [111], [112], [113]:

a. Driver training

In driver training, the focus is made on safe driving, virtually intelligent vehicle simulation, visual attention, following the traffic rules, and learning adaptability to dynamic traffic environments (rainy weather, urban or rural road network), so it is also stated as a driver training simulator [114].

b. Assessment of driver

This is actually the assessment of driver's behavior, where the core demands must be analogous to driving in the real world, and the driver executes a series of standard experiments that are valid and credible. This type of application can be named as a driver assessment simulator [86].

c. Driver Safety

The general objective of driver safety component is to discover the use of virtual reality as probable means for driver training. The specific objectives of the driver safety component are:

1. Transforming or translating real-life driving into the VR world [115].
2. Development of a VR learning situation that can exist as an assessment tool for learning driver behavior in unpredictable situations [116].
3. Performing a series of experiments within the VR world to conclude if the developed learning scenario is effective for training to ensure safe driving [117].
4. Perceiving and processing environment information and presenting this information correctly [118].
5. Gathered information from the experiments conducted can be used to investigate the feasibility of providing safe driving knowledge to drivers and initiating effective practices in the virtual world for future developments in fields of transportation [119].

The driving simulator is used as an assessment tool for the study of driver knowledge related to safety on road. Safe driving, the behavioural study of a driver, traffic flow and vehicle dynamics are some applications of DTS [120].

Urban Development

Since the last 25 years, urban development planning has two standpoints that govern the research discussions. The first perspective is technical and the second one is communicative perspective [42]. To implement these perspectives, the methodology for planning a process is required. Furthermore, urban planning requires a continuous cycle of development between methodology and technology to implement both perspectives. The ever-increasing use of VR technologies can be used for the implementation of both perspectives to plan urban development [42]. During the last decade, 3D computer-aided designing (CAD) and 3D modelling have been used in urban planning. There is a need for the 3D city models and VR simulations implicating technical and communicative perspectives. These will possibly work as an aid to perform scenario-based experiments for urban planning. Advancements in hardware and software technologies accompanied by the iterative development of communication and information technology can help in building such a platform. In a recent study, autonomous vehicle driving and its simulation on urban road networks have been studied [57], [121]. Urban planners are using VR technology which has open ways to new research areas including dynamic environment design, transportation planning, work zone design, and road network modelling. Innovations in the field of virtual reality are indicating the importance of simulation in urban development and planning [122]. It has been adopted in many cities for providing aid to urban planners in planning new and efficient city models. Simulation can be made to perform experiments to check feasibility and fidelity of the suggested infrastructure [5]. VRTram is used for examination of Light Rail Transit (LRT) from aspects of urban planning [123], [124]. Virtual reality GIS was founded in the 1950s. GIS is highly applicable to urban planning [125]. In urban planning quality of road construction projects is an aspect that has an impact on the driver's ability to adapt traffic conditions e.g., bridge designing with respect to current development space [126], [127], [128]. Air quality is also a factor which affects the process of urban planning in the aspect of eco-friendly ITS [129].

1. Intelligent Transportation System

Evolution of Intelligent Transportation Systems (ITS) has shifted the paradigm of transportation at its peak by lowering the risk factor on road. General information and communication technologies are prioritizing intelligent transportation as a vital element of social and economic growth of a country [130]. More challenging problems are evolved in developing ITS because of an increase in the number of vehicles on road. Now for advancement or evolution there is a need for the transport methodologies to be intelligent and efficient [131]. Intelligent transportation systems require new tools like CAD, VR, LIDAR, sensors, latest hardware and software technologies to validate old transportation models. The human factor must also be included while developing an ITS. It cannot be based on the monolithic development of mobility system only. Due to the unpredictability of human behavior, it is not possible to make an intelligent transportation system without studying human behavior in certain potential situations.

2. Transportation Planning

Transportation management and planning has played a vital role in urban planning and development. The past decade has been an era of substantial evolution of using VR in transportation planning and engineering [132]. VR simulations can be developed and experimented on users and urban planners to get feedback for an efficient decision-making process. Simulation tool must include unpredictable and dynamic environment (traffic flows, weather forecast, etc.) [133], focusing on driver behavior, so as to help city transportation planners to make the decision for the regeneration of the efficient infrastructure [134], [135], [136], [137]. Professionals in the field of transportation planning and management can analyze experiments performed on simulation tools to predict the outcome of building a preferred structure on ITS. Different strategies can be applied in a VR simulated environment that will lead to the evolution of new methodologies for transportation planning [138], [139].

3. Work Zone Design

Driving simulators are also used for road safety in the working zone [140]. Implementation of work zone design has following perspectives that need to be fulfilled to avoid accidents and gain in driver's knowledge of taking certain actions in work zone without getting disturbed [141].

1. Design of a work zone that minimally or does not affect the natural flow of traffic.
2. Knowledge building of novice drivers using VR simulation for the required actions to be performed in the work zone.
3. Work zone durations on highways must be of a medium or small duration so that traffic flow is not disturbed for a longer period.
4. Replicating the real environment in VR simulation to perform certain experiments to check the fidelity of the work zone design.

Health

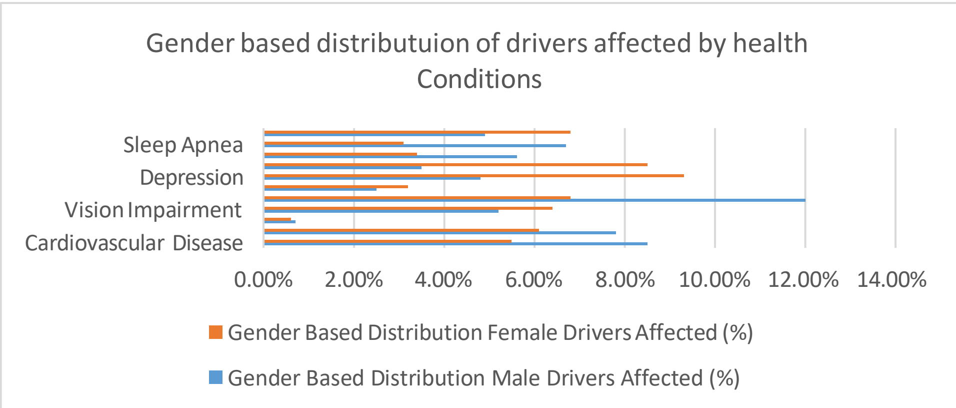
VR training and evaluation systems are being applied within military, education, health, and public settings. With multiple aspects, research is being performed on VR technology and its influence on health. Recently, it is observed as a common approach to studying different health and behavior related aspects during a virtual driving environment [69], [142], [143]. User experience is influenced by the factors affecting his health. The user is evaluated and diagnosed with VR sickness symptoms. Around 65% of users are observed to have an increase in symptoms of nausea [144]. Other diseases diagnosed after using Head Mounted Devices (HMD's) are headache, pain in eyes, redness of the eyes and nausea [144]. The simulator sickness badly influences user performance [145].

1. Psychology

Real-life experiences or psychological impairments sometimes lead to certain phobias in human beings. Phobias pierce roots into human behavior resulting in disturbed daily routine, for example, PTSD (Post-traumatic stress disorder) and agoraphobia [146], [147], [148]. VR simulations can be used to remove the fear of a patient (driver) by making him face the situation that is phobic for him [149]. The mentioned scenario was executed to perform statistical and visual analyses for evaluating the driver's performance and symptoms of phobia [150]. Research studies performed on such scenario have shown improvements in driver's psychological behavior and caused a reduction in the symptoms of driving phobias like anxiety, panic attacks and sweaty palms [151]. Moreover, the study of autistic people while performing in VR driving environments have been reported, previously [109], [152],

[153]. KMRREC (Kessler Medical Rehabilitation Research and Education Corporation) developed a driving simulator for testing the cognitive ability of the driver. The tested drivers were stroke victims and had a traumatic brain injury. Drs. Simone and Schultheis have stated that this simulator will enhance the sense of presence of the patients [154]. Driver's fatigue and distraction are one of the cognitive aspects that cause road accidents. Auditory warnings can also be used to enhance the sense of presence [155], [156], [157]. Head up displays are recently being used in the field of automotive research. Head-up displays (HUDs) decreases driver's reaction time because of improvement in cognitive ability such as spatial awareness [158]. People are reluctant to drive because of their health conditions that has affected both physiological and psychological. Figure 3. below depicts the gender-based distribution of US drivers affected by health conditions.

Figure 3: *Gender based distribution of US drivers affected by health conditions*



2. Driver Behavior

Driver Training System (DTS) is ever more used for training drivers, but uncertainties like practical realization and immersion still are major problems, when the validity and reliability of a simulator for accident prevention is concerned [159]. Driver behavior, while driving in virtual environments, has been studied previously[153], [160], [161]. To check the fidelity of the DTS in accident prevention following must be considered.

1. Dynamic environment.
2. Previous experience of the trainee.
3. Incapability to predict behavior of drivers in the surrounding on the road.
4. High-speed vehicles.

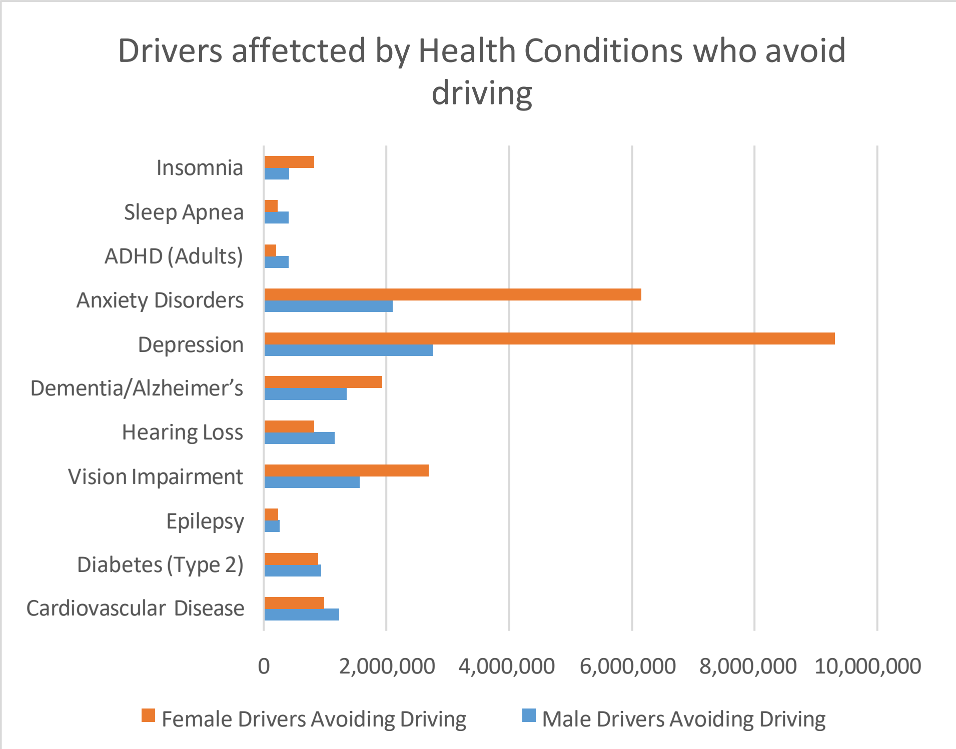
5. The minimum distance required to take safety measures in uncertain situations.

Previous knowledge or experience significantly affect the speed adopted by the driver [162], [163]. Unpredictable traffic flows are a cause of accidents and injuries due to the previous experience of a driver [164]. DTS can be applied as a supporting tool in the process of urban transportation planning. Use of a DTS is a significant approach to foresee the safety effectiveness of preferred transportation plan in urban development, thus it is a cost-effective solution. Driver behaviors are studied using VR simulators such as TranSim [118], [165]. Driver Rehabilitation simulators are designed which measures user feedback and comfort for refining the decision-making ability of the driver by providing assistance using different techniques [166], [167].

3. Physical Injuries

The capability to drive a vehicle is a significant skill for people with a physical injury to maintain perfection in life. But for that it needs frequent installation of an ADS (Adaptive Driving System) to control acceleration, deceleration, and steering [168]. Some recent studies depict the effect of injuries on driving performance [169], [170]. VR based environment is designed, in which the driver's pulse wave is recorded while driving. Experimental data illustrates the physiological response while performing manoeuvres [171]. ADS consists of two types of Adaptive Driving Controls (ADC) that are electrical and mechanical [47]. Electrical ADC works by transforming generated electric signals into motorized actuators [172]. DTS is worthwhile for ADS because they let users to experiment diverse control devices like Antilock Braking System (ABS) and Adaptive Cruise Control (ACC), to rehearse driving without the risks of presence on the road. Furthermore, it can be used to assess disabled drivers in a safe manner e.g. National Highway Traffic Safety Administration (NHTSA), which is an ADS and supports disabled drivers by accommodating their driving needs [173]. Figure 4 depicts drivers affected by adverse health conditions that avoid driving.

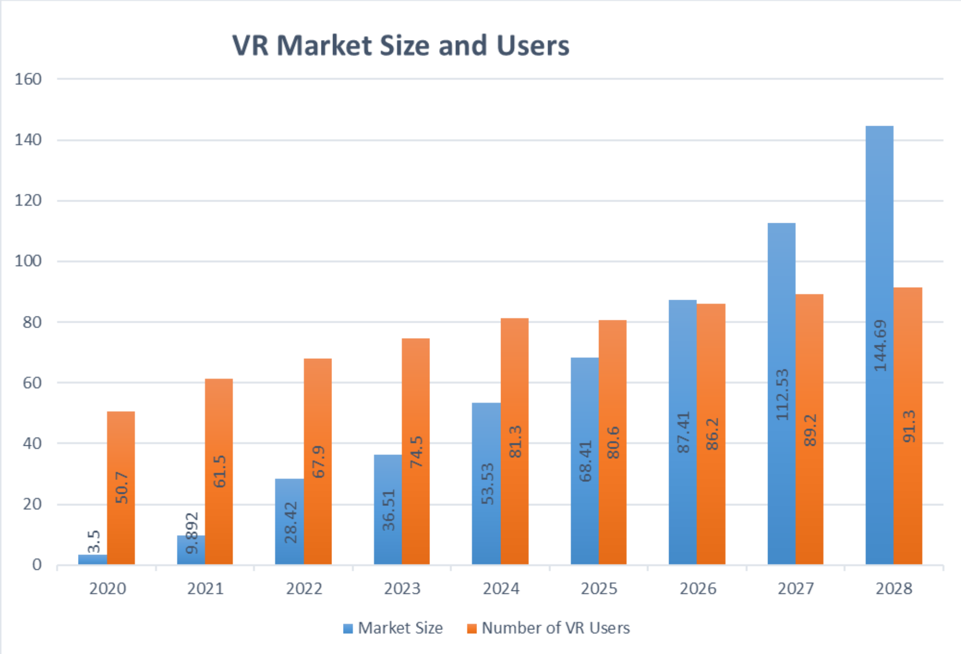
Figure 4: *Drivers affected by adverse health conditions*



Virtual Reality Supported Training Systems

Virtual environment (VE) supported training systems are more widespread than ever due to improved VR technology. VR based driving simulators have a signified challenge for VR technology [174]. VR based applications are growing rapidly in every field of life including education, health care, entertainment, engineering, fashion, business, and transportation [175] as they are facilitating with the realistic and cost-efficient environment. VR refers to the use of computer modelling and simulation to enable a person to interact with an artificial three-dimensional visual or other sensory environment such as goggles, headsets, gloves, or bodysuits [176]. A serious game is a simulation-based learning tool, designed to focus on a primary purpose, rather than pure entertainment, providing interactive learning environments using gaming interfaces familiar to the end-users [177], [178]. Many research studies and reports recommend the use of virtual reality in training users to conduct tasks that are either too costly or too dangerous to perform in real life [179], [180], [181]. Venture investments from 2020 to 2028 are depicted in the Figure 5 below. Data is collected from Nielsen's super data.

Figure 5: *Venture investments from 2020 to 2028*



Conclusion

Training is an important part of getting skilled in any of the profession. Conventional methods of training for many of such professions are very expensive and sometimes life-threatening. For example, to assess a driver in a certain environment will require an environmental setup and repetition of assessment, which is an expensive task to perform. Such assessment can cause severe injuries, pollution, and may apply many constraints on understanding and performance of the trainee. To overcome all these problems, VR based training systems have been developed and used, which have improved their training mechanisms. Such training systems have made great progress in the last decade. Such fields of work include medical training, military training, driver training, and urban development This paper has introduced DTS, ITS and transportation planning using virtual reality within a training context. We have represented a survey which can be used to implement stated features in future in VR to achieve high efficacy and cost-effectiveness in building Intelligent Transportation System (ITS).

Limitations

While this review presents a comprehensive synthesis of VR applications in transportation research, certain limitations must be acknowledged. The literature search was limited to selected academic databases and publications in English, which may have excluded relevant studies in other languages or less-accessible sources. Variations in study quality, sample sizes, and the rapidly evolving nature of VR technology introduce challenges in drawing uniform conclusions. Additionally, many included studies were conducted in controlled environments, which may not fully capture the complexity of real-world driving situations. These factors should be factored in when interpreting the findings and considering future research directions.

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