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Using VR Technology as an Urban Design Assessment Tool: A case study of Jeddah

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ABSTRACT

In the last few decades, virtual reality (VR) has been grown to become a vital tool used for visual communication due to its efficiency in personal experience and interaction. Most of VR applications have used for video games, graphic design and media; however, it can also be used for further applications based on the purposes, functions and fields. This study aims at exploring the use of VR techniques in the field of urban design. Therefore, this paper attempts to discover the effect of using VR as an assessment tool in urban design projects before the implementation/execution phase to avoid any future implications and errors. These will be tackled by applying VR in developing a designed simulation for urban design practice by creating a VR environment for existed projects. In a VR environment viewer will experience a walkthrough of one case study of an urban void under flyovers in Jeddah city. Shortly, the research will suggest that the use of VR technology may enhance the visual communication between the viewer and experts. In order to achieve this, the authors used the POE method to evaluate the current situation (by interviewing the various stakeholders) and the new development based on the PPS criteria (via VR simulation) to improve the quality of the urban void. Al-Darrajah roundabout flyover has chosen for the virtual walkthrough experiences.

1. Introduction

Urban design projects are facing many issues regarding the design and execution, which might need further assessment due to its importance on urban development [1]. Therefore, planners and urban designers have already started to take advantage of the three-dimensional (3D) visualization tools arguing that the full interactive visual environment. 3D visualization increases the possibility of understanding the illustration and presentation of an idea and project development [2]. Moreover, Virtual Reality (VR) has abled designers to simulate real-time environments with several degrees of realism due to its dynamic and interactive characteristics [3][4].

This paper aims to explore the use of VR techniques in the field of urban design. The authors utilize the use of VR in assessing one particular urban comportment within cities' urban fabric; in this case, the urban voids under flyovers. It is highlighting the proper guidelines for managing the uses of urban voids project, which may improve the quality of urban design project. Jeddah city has chosen for the study due to several reasons. Firstly, since 1950 Jeddah has been under a dynamic urban development, and secondly, the variety of the city land uses [5]. Lastly, Jeddah city had and still facing an expansion within the urban context that affects the city social image and community behaviours [6].

Figure 1 illustrates the conceptual framework of the research paper, highlighting the problem, the assessment tool and the project parties involved within the experiment. Finally, this paper is attempting to explore the integration of VR as a tool in the process of development, and decision-makers can use it as an efficient method. An urban void will be studied to understand how VR can play a significant role in the design and execution phases.

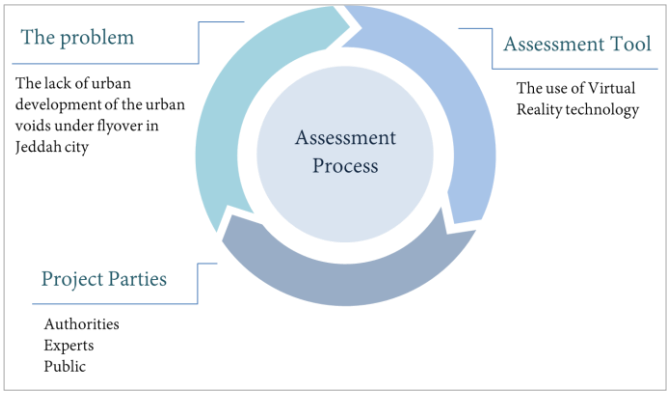

Figure 1. The study scope [7]

2. Research Methodology

The methodology of this research focuses on the mixed approach of qualitative and quantitative data collection using the Post-Occupancy Evaluation (POE) method via the Project for Public Space (PPS) criteria to get the comprehensive development. POE method helps the researchers to enhance the quality of the collected data and improve the opportunity to fully explore the study topic that has designed to be addressed via observation and interviewing the various stakeholders [8]. In addition, POE method focusses on architecture and urban projects improvement and provides feedback (by the various stakeholders) throughout the occupied project for a length of time [9][10]. Moreover, certain factors have to be taken into consideration to achieve the highest quality of the space such as uses and activities, sociability, access and connections, comfort and image [11]. For the case of the voids under flyover, the access and linkage are the most critical factors to achieve the high quality of space, as the surrounding of the flyover is differing from an area to another. The study of re-connecting the void to the urban context requires the consideration of the level of traffic and pedestrians to achieve safety access to the space. Therefore, the Project for Public Space (PPS) in 2009 has

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developed criteria to evaluate the success of space to transform (Figure 2) the unused space into a public space for community engagement and socializing which are; access and linkage, comfort and image, uses and activity, and sociability [12].

Figure 2. Criteria for evaluating the quality of transforming a space to an active place [12]

The research focuses on two main pillars that work connectively: the source (the prime data) and the viewer (via VR environment) to achieve the research goals (Figure 3). Firstly, the source data for the urban void development the paper used POE method via PPS criteria to get the comprehensive development through: observation (by the authors) and interviewing the stakeholders (users, authorities and experts). The result of this phase (source of development) transferred into multiple urban design decisions via 3D modeling design (VR content). Secondly, the transferred data studied by the various stakeholders to understand their precipitations, evaluations and satisfactions before execution phase. Figure 3 presents the research methodology flow that used in this research. Finally, this type of research requires a case study method, which is one of Jeddah's urban voids that unused properly "Al-Darrajah roundabout flyover void". Figure 3 illustrates the methodology flow used in this research.

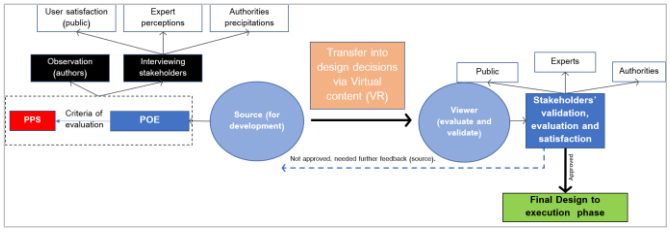

Figure 3. Research Methodology flow [7]

3. Historical Background of the development of VR Technology

Virtual Reality (VR) or Virtual Environment (VE) offers a unique experience of a three-dimensional surrounding where the viewer can experience things that are not accessible in real life or even not yet created [13]. This technology used in the 20th century from architects, designer, engineers were bringing fast technology to the market [14]. However, the first virtual experience developed in 1838 – Stereoscopic photos & viewers by Charles Wheatstone [15]. The stereoscope has opened a new world by manipulating pictures presented to each eye and observing the depth that was produced (Figure 4).

In 1929, Edward Link invented the link trainer as the first commercial flight simulator. It had designed and invented to help in effectively training pilots. The link trainer has been used to train over 500 US pilots during the second world war [16]. By the 1950s, the Sensorama developed by Morton Heilig, which is a device stimulates all senses as it enables the viewer to be fully immersive within the experience figure (Figure 5). It has a stereoscope colour display, sounds, vibration, and creates an environmental atmosphere as wind blowing and movement [17].

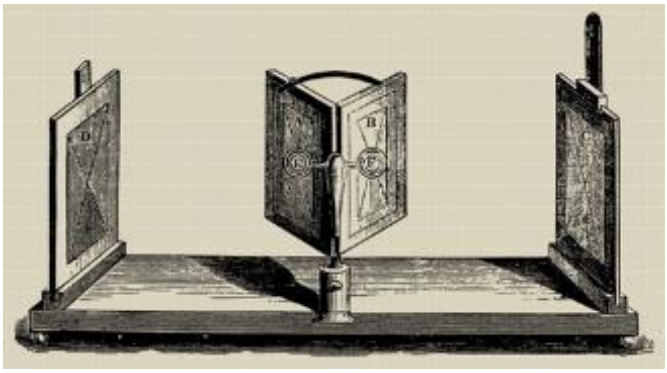

Figure 4. The initial idea of VR by Charles Wheatstone "Stereoscopic" [15]

By 1968, the Sword of Damocles, by Ivan Sutherland and Bob Sproull, the scientist who created the computer program Sketchpad as a tool for human interaction. Moreover, Ivan had gone a step further in developing the virtual simulations through inventing what is now known and consider the first head-mounted display (HMD). However, during this time of invention, the engineer Thomas Furness have developed a flight simulator project called Super Cockpit. It has helped the pilots controlling the aircraft as it linked to infrared and radar imagery and sense eye movement and speech [2].

At the beginning of the 1980s, the name of virtual reality has been born, Jaron Lanier, the founder of the visual programming lab (VPL), coined the term of "virtual reality ", within his research lab he developed a range of virtual reality gear [18]. Also in the 1980s, NASA Ames research centre constructed the prototype of the NASA Virtual Environment Workstation built from a motorcycle helmet, Watchman LCDs, wide-angle stereoscopic optics, and a magnetic head-position tracker (Figure 6). The Virtual Environment Workstation incorporated the first data glove used in virtual reality. The glove measured the bending angles of the finger joints, and it included a tracker to measure the hand's position and orientation. Thus, the user's gloved hand could interact with the virtual world grasping virtual objects or using hand gestures as commands [19].

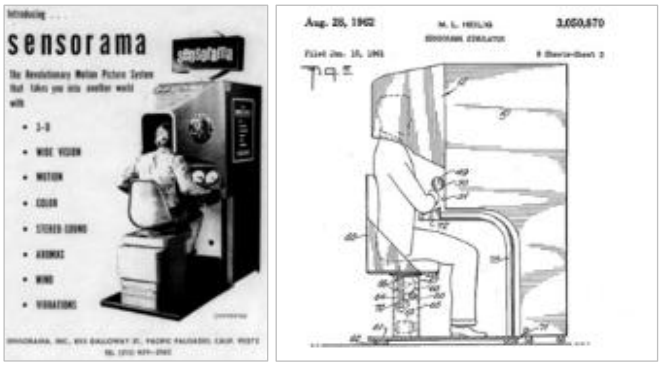

Figure 5. Sensorama by Edward Link [20]

Later in 1992, Sega has introduced the Sega VR headset (see Figure 7) for the public, and from there, developers started to develop the technology of virtual reality. This technology has introduced to millions of people to this innovative idea, such as introducing the matrix movie in 1999 as a virtual reality movie and gaming [21]. The VR technology has developed with less equipment and more details, which led planners and architects to start to look at VR technology as a tool of illustration, imagination and creation before execution.

Today, design, in general, has been entirely developed and using technology becomes a crucial tool. Therefore, VR developed to enhance design processes. VR, as an advance of current computing technology, appears to be the next logical step in the design field because not only is it a sturdy and immersive acting tool but its ultimate product can also improve with augmented and mixed facts [9].

Figure 6. NASA's virtual station [22]

Figure 7. SEGA VR [23]

4. The VR Technology and its Applications in Urban Design

"Virtual reality (VR) can be defined as a medium composed of interactive computer simulations that sense the participant's position and actions and replace or augment the feedback to one or more senses, giving the feeling of being mentally immersed or present in the simulation." [24]

VR has been recently used to improve many types of design, but this paper focuses on one type "urban design". This type of urban visualization with the use of VR technology helps urban planners and designers to fully understand the created 3D model by being fully immersive within the environment [18]. Additionally, "Three-dimensional city models are characterized by their level of detail (LOD), a concept that describes their complexity and fineness" [19]. Furthermore, the concept of LOD is sort into five levels to enable an efficient visualization and data analysis; starting with LOD 0 which specified in visualizing the regional and landscape, LOD 1 focuses on the city and region, LOD 2, used in directs and neighbourhood projects, LOD3, envisions the exterior of the architectural models and landmarks, and LOD 4 for the building interiors (Figure 8) [25][26].

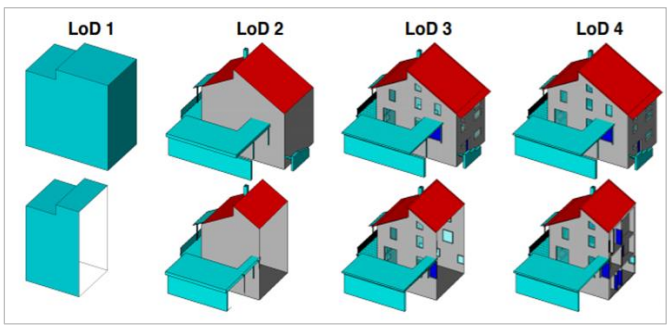

Figure 8. Different levels of Details based on CityGML. [21]

Besides, the VR simulation aims the following: firstly, to evaluate the VR experience and the impressiveness' quality levels. Secondly, to assess the applicability of integrating the technology within the urban developments. Lastly, to determine the different uses of VR within urban development [27]. In short, the VR simulation develops a walkthrough experience that offers the clarity of viewing urban design developments. In order to achieve the ideal objectives form VR technology, virtual equipment must be used [28][29]. These types of equipment enable the viewer to be fully immersive and interacted within the three-dimensional environment, then trying to create or imagine the most appropriate urban design methods before execution [30]. This paper illustrates three different examples of using VR technology for developing urban design projects to shed lights on the importance of this technology in the future of design.

Firstly, the case study of virtual Singapore has illustrated the possible abilities of VR technology is affecting urban management and visualization. The project provides possibilities for expertise to explore virtually different sources of static and real-time city-data. The virtual model provides information about the traffic condition, building materials and also simulates different scenarios of the wind flow, the sunlight direction and the study of building ventilation (Figure 9) [31]. According to National Research Foundation Singapore "It will enable users from different sectors to develop sophisticated tools and applications for test-bedding concepts and services, planning and decision-making, and research on technologies to solve emerging and complex challenges for Singapore." [32]

The developers of the project are expecting that the virtual model of Singapore will benefit the stakeholders as it will enable public agencies, academia and the research community through using the information and the system capabilities in different business analysis and decision making. To conclude, the virtual project will be providing a realistic platform for citizens and government in creating awareness and providing services, as it will allow for the creation of innovations and technologies for public and private collaboration adding value to the city of Singapore [32].

Figure 9. Virtual Singapore 3D model. Picture from: National Research Foundation. [32]

The second example is the urban development of Khalifa Street Al-Ain city, Abu Dhabi, UAE. This street was selected because it considers the densest area in the city of AL-Ain, consist of a lot of vegetation and landscape elements, detailed buildings and comfortable street furniture and traffic. The project aimed to enhance "the imagine-ability compromised both built and natural environments and human perception and cognition" [33]. This project started with observation study to understand the current street situation, issues and opportunities, then followed by the simulated virtual models that aimed to meet three criteria: (1) To achieve a certain degree of realism (2) To meet bandwidth restrictions regarding file size (3) To navigate smoothly and download time and easy to construct to meet the budget constraints.

El-Araby and Okie [33] tested the model in three different stages (see Figure 10): First, raising all building heights in the area to six stories instead of using the current height four stories, which showed no difference regarding the street appearance by 20% total trees reduction. Second, raising the buildings of the street edges and in the centre of the building to six stories, which also did not affect the street appearance by 40% of total trees reduction (stage2). Finally, raising buildings heights on the street edges to nine stories, a change that has been observed by 60% of total trees reduction (stage3).

Figure 10. The three stages of real-time simulation of Al-Kalifa Street. [33]

El-Araby and Okie [33] also have attempted to change the different design scenarios to evaluate the effect of the new design of the street (Figure 11). the options for changing elements within the environment are endless, and the study model has proved that the VR can be a reliable and efficient tool in noticing the different impacts of changes on the built environment, which can be an attempt of further study. Moreover, the tool has enhanced the potentials of urban visualization and modification.

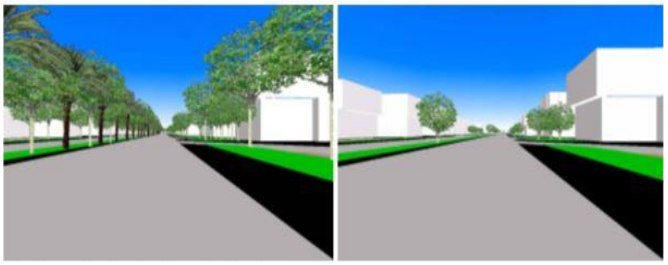

Figure 11. The result of changing trees, heights and types. [33]

This above example had excluded the experts, authorities and public opinions and perceptions from the circle of the urban design. Therefore, the authors claim that the new design scenarios have to be based on all of most of the stakeholders' interventions to ensure the needed upgrade for selected urban space.

The final example is a pilot project has been proposed to develop four bridges in India: Shahibag R.O.B, Jivraj Mehta R.O.B., Soni-ni-Chali Bridge and Thakkarbapa Nagar Bridge. The bridges were planned mainly to improve the vehicular flow, which caused an impropriate use under the bridge. The development has been proposed to enhance the spaces facilities through lighting, signages, and waste collecting, also improving the linkages across the bridge under-spaces through redesigning road intersections under the initiative been done by Ahmedabad Municipal Corporation (AMC) [34].

Figure 12. Improving the social level under the flyover, India. [34]

The initiative by AMC aimed to improve the urban environment and reclaim the underutilized spaces under bridges and flyovers through enhancing the connectivity and urban social level through set up a VR enrvionment (Figures 12 and 13). Firstly, creating public spaces such as parks, shaded seating areas, food courts, gathering spaces, plazas and play areas. Second, providing vending opportunities in dense neighborhoods through kiosks, markets, and vending zones to attract the public. Third, improving overall pedestrian connectivity. Fourth, providing public facilities such as autorickshaw stands, public toilets, and strategic parking. Fifth, Facilitating these spaces by lighting, signage and waste collection. And finally, improving linkages across the bridge under-spaces by redesigning road intersections under the bridge [34].

Figure 13. The accessibility and linkage under a flyover. [34]

Besides, the development of the urban voids project mainly focused on the user's experiences (public opioin that transsfered into 3D modeling and VR envioment), and it enhanced the community participation during the planning process. This factor is necessary to be considered within the developments [35], as it will enhance the quality and improve the outcome of planning and designing. In short, "Meaningful community participation extends beyond physical involvement to include generation of ideas, contributions to decision making, and sharing of responsibility" [36]. Thus, public participation and involvement is two-way communication and collaborative problem solving with the goal of achieving better and more acceptable decisions. Additionally, citizen participation is being used as a tool [37]. The source of the new deveopment have been set up by AMC involved the publuc only wihout the other satkeholders (experts for instance) which migh not have a commperhasive point of view. Thfreoe, this paper imphsisisves in ivlovolig the avalaible stakholders to ensure the approticne of the new urban design devleooment before execution.

5. Using VR Technology to Develop Al-Darrajah Roundabout

As mentioned previously, POE method provides a long-term benefit for future development; it been used in this research paper to offer different possibilities for evaluation. Moreover, the range of tools and techniques can be used during the POE in collecting multiple types of data; observation, interviews, questionnaire, and walkthrough [38]. This research paper aims to incorporate the use of virtual reality technology as an assessment tool in urban development. It is using the tool in assessing the development of an urban void within the city of Jeddah mainly for the case.

5.1. The case study

The method of case study helps the researchers to examine the data within a specific context; the case studies can be selected based on a geographical area or an individual [39]. Moreover, the case study approach has the potential in dealing with different situations, by enabling the researcher to answer the questions of "how" and "why," by considering its context [40]. The case study selected for this research is set in the urban areas of Jeddah city to evaluate the current situation of urban voids under flyovers, namely Al-Darrajah [Bicycle] roundabout that located in the centre of the city urban fabric (Figure 14). However, the primary data collected from observation, a virtual simulation of the current situation and interviews of the experts, the local authorities and end-users (public).

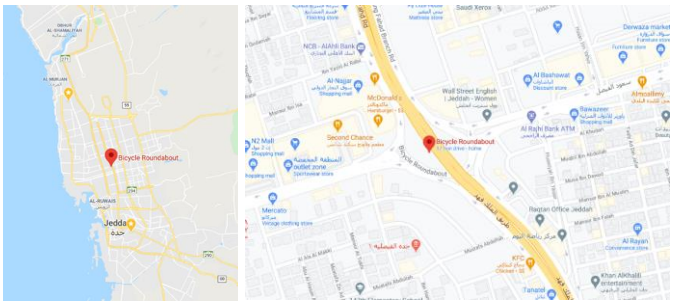

Figure 14. The location of Al-Darrajah roundabout with Jeddah's urban fabric [41]

5.2. Observation

Observation helps the researchers to gain a deep understanding of a specific problem or event. Observation involves the use of senses such as the eye, nose and voice [38]. This study focuses on observing and evaluating the urban voids under and surround the flyover of Al-Darrajah roundabout based into POE method and PPS criteria. The observation phase conducted during six months from January to June 2018 by the authors, in order to recognize the urban void design and the user's behaviour that both will affect the design of the virtual experience, which will illustrate the development of the urban void.

The urban void of Al-Darrajah roundabout is located in Al-Faisaliyah district, the intersection of King Fahd Road and Al-Rawda Street, linking three adjacent neighbourhoods [42]. The urban void under a flyover with a length of 583m with a width of 13.5m. Due to the construction of the flyover, it gave a significant organic shaped urban void of 138m x 234m. Al-Darrajah roundabout has an esthetic value for the city of Jeddah, it been designed by the Spanish architect Julio Lavonte, who created his fingerprint within the city by creating masterpieces in each area [42] (Figure 15).

Moreover, the collected data of the urban void period has been validated by taking pictures of the urban voids passerby activities such as cycling (Figure 16) and tracing the footprints of each user to fully understand the urban void atmosphere for the virtual experience development. Furthermore, the urban void is surrounded by a variety of mixed-use buildings. It worth mentioning that the adjacent buildings are existing commercial buildings along the side of the nearby streets (Figure 17). It worth mentioning that the functionality of the void does not provide any support to the value of the area. It is fully exposed to the sun as the span of the flyover does not provide shades for the whole void. In summary, the urban void of the roundabout is used by the residents as a transition area to reach different areas within the neighbourhood. Also, it has been used as a dumping area for buildings and commercial shops waste (Figure 10). However, it was notable during the periods of observation the changeable weather was the main reason for the users or passers behaviour.

Figure 15. A photograph of Al-Darrajah roundabout. [43]

Figure 16. Users cycling within the existing urban void which is not applicable for such uses [43]

Figure 17. Al-Darrajah roundabout urban void surroundings. [43]

To conclude, there are multiple lacks of the current design of the urban void Al-Darrajah flyover based on the physical observation that conducted by the authors before the VR transformation that summarized on Table 1.

Table 1. The authors observation evaluation and comments based on POE method and PPS criteria [7]

Crietirea (PPS)	Observation summary			
	POE evaluation			General Comments
	Suitable	Moderate	Not Suitable	
Sociability			✓	No social activities in the urban void, for example the urban void has no welcoming or interactive elements, which led to decrease the urban image of the space.
Uses & activities			✓	The urban void used only as roudnabout of automobies transformation, and it can play a signifcant role as active urban void linking to side of the street.
Access & linkages			✓	Disconnection between the two sides of the roundabout (divided the voids into two separated areas). No respect to the various users' needs (for instance, no access for handicapper and cyclist users).
Comfort & image		✓		The urban void has no safety elements for the pedestrian to cross the roundabout, such as no hardscape elements to reduce the car speeds. In addition, no softscape elements (trees for shading). Regardless the above comment the urban void has a strong image to the city because of the bicycle abstracted element but it needs to be developed by adding the local identity to the space.

5.3. Interviewing stakeholders

The researchers conducted interviews the various concerned stakeholders to understand their perceptions, evaluations and suggestions to develop the urban void based on the methodology used. The researchers have categorized the responses of the interviews based on the experiences of the interviewees as follow: potential end-users "the public", local authorities, and experts.

Firstly, a random sample (450 persons) form the potential end-users have been interviewed by answering a survey (questionnaire). This survey was designed for those who use the urban voids on a regular basis to understand their needs and perceptions for the place and their satisfactions. Secondly, interviewing two officers from the local authority "Jeddah municipality" to understand their perceptions regarding the urban voids under flyovers in Jeddah in general and Al-Darrajah roundabout in particular. Interviewing the authorities has

shed some lights on their understanding and perception for the unused urban voids. Finally, 15 experts were interviewed (semi-structured interviews) from different fields such as local architecture, planning firms; academics from Effat University and King Abdul-Aziz University and experts in different fields as architects, landscape architects, civil engineers and urban planners' planners. Such interviews shed lights on the understanding and evaluation of the expert to the urban void (Table 2).

Table 2. The interviewees' improvements based on their types before the VR experiment [7]

Criteria (PPS)	POE evaluation															
	The public (450)				The authorities (2)				The Experts (15)							
	User satisfaction of the urban void				Evaluating of determined actual implementation in the respective area				Correlation between space performance and space quality.				Performance meets with user needs and requirements			
	Satisfy		Dissatisfy		Suitable		Not Suitable		Suitable		Not Suitable		Suitable		Not Suitable	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Sociability	12	2.6	438	97.4	1	50	1	50	1	6.6	14	93.3	4	26.6	11	73.3
Uses & activities	15	3.3	435	96.6	2	100	0	0	2	13.3	13	86.6	1	6.6	14	93.3
Access & linkages	6	1.3	444	98.6	1	50	1	50	4	26.6	11	73.3	3	13.3	12	86.6
Comfort & image	156	34.6	294	65.3	2	100	0	0	5	33.3	10	66.6	3	13.3	12	86.6

Table 2 presents the evaluation of the urban void based on the stakeholders understanding and precreation. It seems that the vast majority of the public sample were not satisfied with the current urban void design. On the other hand, the authorities' sample is almost 50% happy with current situation. Finally, the expert sample has critical issues with the urban design based on PPS criteria in all levels.

However, the authors have collected variety of suggestions form the various stakeholders to improve the designated urban void based on the methodology used. Eight significant improvements were suggested by the different stakeholders, as shown in Table 3.

Table 3. The various stakeholders' suggestions to develop the urban void [7]

The improvement	The stakholders		
	The public	The authorities	The Experts
Functionality & space qulility	Link the two areas with a clear and safe path.	Make the urban void easy for transportation.	Clear and safe accesses. Link the two areas in a good way.
Appropriateness & durability	The urban void needs more innovated features to be developed.	Using appropriate materials and elements fit with the location and different conditions.	Using materials that fit with the extreme weather condition in Jeddah.
Users' needs & safety	More shading elements, and areas for resting. Needs more safety elements for pedestrians, cyclists and disabled users.	More safety tools for the pedestrians.	Using speed reduction tools, such as bumps, signs and Zebra crossing lines. Make the urban void applicable for all types of users.
Aesthetic & idinenitiy	Adding more beautiful and colorful elements.	Make the place hub for street users.	Landscape (hard and soft elements). Emphasizing the bicycle statue.

The authors have transformed these suggestions (Table 3) into one ideal design (with multiple options) that can cope with all suggestions with taken into consideration the international, national and local measurements, laws and regulations. The first step was to produce a 2D plan and 3D modeling design (via 3Ds Max Program) based on the authors' observation and the interviewees responds (Figures 18 and 19). Then, the result was validated and evaluated by the stakeholder via a VR simulation that presented to different samples from the above interviewees' categories in order to explore the capability of using as an assessment tool in urban design projects. The following part of this paper illustrates the VR experiment through the available samples from the different stakeholders' categories.

Figure 18. A 2D plan design bases on the responses [43]

Figure 19. The final 3D modelling for the new development based on the observation and interviewers/ surveys [43]

5.4. VR Simulation:

Al-Darrajah urban void simulation environment has combined the level of details LOD 1, LOD 2 and LOD 3. Hence, LOD1 illustrated the city planning details, LOD2 illustrates more details within the districts and neighbourhood projects, and LOD 3 for the landmark. This happened through using unity software (3Ds Max program) for the three-dimensional model (Figure 20) and the HTC Vive headset and controller for the virtual equipment (Figure 21). These pieces of equipment enable the viewer to be fully immersive and interacted within the three-dimensional environment in order to evaluate the new design development based on the pervious results.

Figure 20. A three-dimensional by 3D Max Low poly model for the urban void using a LOD1, LOD2 and LOD3 [43]

Figure 21. HTC Vive consists of headset, controllers and the camera. [44]

As the study aims to propose VR technology as a tool in urban development, the authors have conducted VR simulation sessions with the available sample of public (10), local authorities (2) and experts (10) to evaluate the efficiency of VR technology in developing urban design projects before the execution phase (Figure 22). The issue was during conducting the VR simulation with the public sample because it needs a place equipped to conduct the experiment. Therefore, a selected sample form the public has been chosen to conduct the experiment, and the sample has to one of the participants in the previous survey that presented in Tables 2 and 3.

Figure 23 illustrates some of the viewer walkthrough experience while using VR technology. It is a 1:1 experience, and the viewer can move freely 360 degrees with no restrictions, and they can feel the difference in levels and heights. The authors have communicated with the interviewees verbally and visually (using the computer program) during the simulation sessions to add notes and suggestions regarding the new design for the urban void and for the technology itself. The experiment results "visualizing the new development of the case study through an immersive experience" has succeeded with all samples without any apparent errors.

Figure 22. During the VR experiment [43]

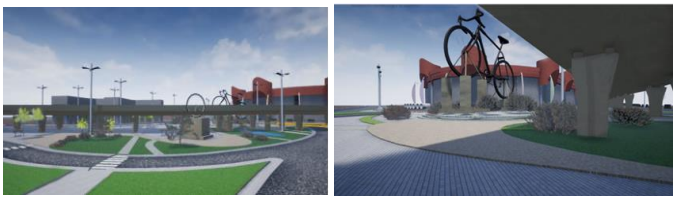

Figure 23. The viewer walkthrough experience [43]

As it presented previously, the authors have collected the different evaluations of the various stakeholders before the new development and the VR production (Table 2), however, Table 4 presents the sample evaluations to the new development via VR experiment. Table 4 presents that (11%) of public, (100%) of the authorities' and (66%) of the experts' samples were available to validate and evaluate the new design development to Al-Darrajah roundabout. In addition, it seems from Table 4 that vast majority of the entire samples were happy with the new development that happened throughout the pervious phases.

Table 4. The interviewees' improvements based on their types after the VR experiment [7]

Crietirea (PPS)	POE evaluation															
	The public (50)				The autorties (2)				The Experts (10)							
	User satisfaction of new devleopment				Evaluating of suggested design				Correlation between new space performance and space quality				Performance meets with user needs and requirements			
	Sasitify		Distisify		Suitable		Not Suitable		Suitable		Not Suitable		Suitable		Not Suitable	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Sociability	48	96	2	4	2	100	0	0	9	90	1	10	8	80	2	20
Uses & activities	49	98	1	2	2	100	0	0	10	100	0	0	7	70	3	30
Access & linkages	50	100	0	0	1	50	1	50	9	90	1	10	10	100	0	0
Comfort & image	50	100	0	0	2	100	0	0	9	90	1	10	9	90	1	10

5.5. Validate the results

In order to validate the results of the VR experiment, the authors conducted a survey to all stakeholders asking their evaluations to the VR experiment in developing such projects. The collected data from the survey has stated that VR technology could be a helpful tool for urban development by using the tool between the phase of design and the finalization of the project. This has been done by illustrating a developed urban space via a virtual walkthrough experience, and 72.5% of the sample have preferred the development through the immersive world due to its three-dimensional impact (Figure 24). Based on the same survey (see Figure 25) 80 % of responses have agreed on using the tool as an assessment tool as it could provide benefit in term of improving the quality of the urban development. Also, it can be a way of urban quality management tool. VR simulation gives freedom of movement within the environment as it will enhance the relationship between the designer, the viewer and the decision-makers. Also, figure 25 shows that 93% of the sample were "very happy" with the results, 5% have some comments for further development, 45% have never been involved or consulted in developing projects in the city, and finally, 75% emphasizes the importance of using VR in all public design reading urban design due to the efficiency and accuracy of the results.

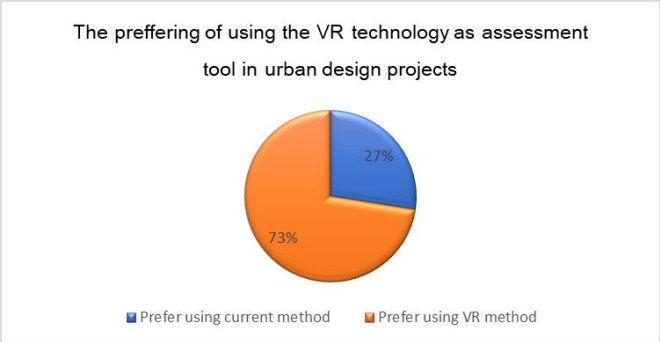

Figure 24. Surveying stakeholders of their opinion of proffering use VR technology as an assessment tool in urban design projects [7]

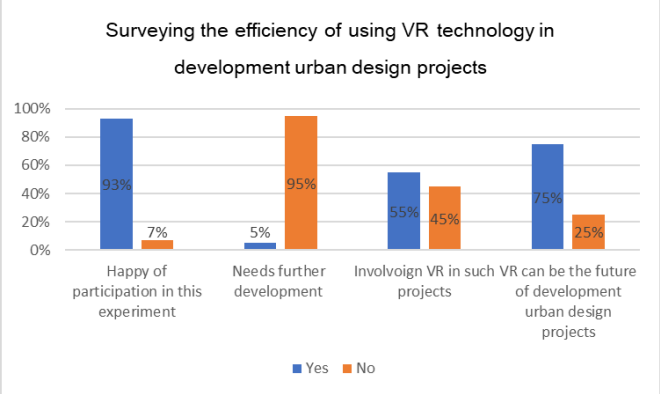

Figure 25. Surveying the efficiency of using VR technology in development urban design projects based on the stakeholders' opinions [7]

6. Discussion

This research paper has discussed the use of VR as an assessment tool in developing urban voids. The integration of VR technology and urban void development was done to achieve the research purpose by exploring urban development and valuable uses of urban voids under flyover through a virtual environment. Also, the study has analyzed and explored the different uses of VR within the urban project for several aspects: urban development, urban management, and urban visualization. Figure 26 summarizes the suggested flow of using VR technology between the sources and viewers to achivew the comperhanisve design proposals before the excuioins phases. It seems from the experiment that VR can play a significant role in enhancing the urban design projects before the excision phase because it allows us to imagine the place. This technology is available and affordable. Also, it is the logical next steps, especially with the current challenges that our globe is facing, such as COVID 19 crisis. For instance, VR technology can be used remotely from a distance.

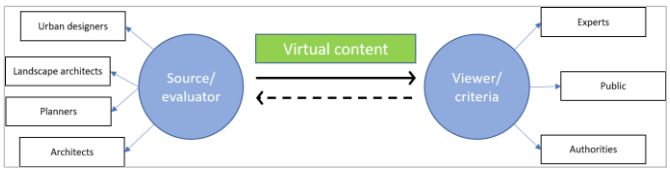

Figure 26. The flow of using VR technology to develop urban voids [7]

7. Conclusions

In conclusion, this paper has discussed the possibilities of using VR as an assessment tool in an urban design project before or after implementation or execution to avoid any future implications. To enhance and improve a virtual experience, it recommended the following: 1- to provide models physics and occlusion to enhance the reality of the placed elements and create a more realistic walkthrough experience. 2- to import more realistic elements such are care movement and pedestrians. 3- include the virtual reality experience within the project time frame. 4- provide the option of switching between different scenarios. Finally, VR can be integrated into the project management phases as an assessment tool for future urban projects developments.

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