Cloud-based Virtual Reality Integrated Automatic Presentation Script for Understanding Urban Design Concepts in the Consensus Process

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Cloud-based Virtual Reality Integrated Automatic Presentation Script for Understanding Urban Design Concepts in the Consensus Process

A Case Study of One Foundation's Disaster Prevention Park in China

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Abstract: In recent years, designers have used various types of tools, such as public Participation GIS (PP GIS) and Virtual Reality Modelling Language (VRML), to improve urban design concept understanding in the consensus process. However, these tools were frequently criticized as being too complex for the majority of potential users. Moreover, due to the limitations of data compression, hardware performance, network bandwidth and costs of current virtual reality platforms, the users need to gather in the same place and at a certain scheduled time in different phases, or download the virtual environment and avatar models from the server through the Internet, then host on the local computer. Cloud-based virtual reality technology is acknowledged as a powerful tool, which provides a communication platform for users. In this research, we contribute an example of a cloud-based virtual reality (Cloud-based VR) integrated automatic presentation script (APS) for providing a broader way for users to participate and understand urban design concepts in the consensus process. We took One Foundation's Disaster Prevention Park in China as a case study, and built a Cloud-based VR platform to propose design concepts, and create an APS for auxiliary guidance of users toward understanding the concepts of urban design and deliberate design alternatives in a design report meeting through the Internet. The application results show that the Cloud-based VR (integrated APS) platform proposed in this paper can not only simplify the discussion of design concepts without the limitation of space and time, but also can improve the efficiency of discussion around design alternatives to reach a consensus without any extra expense.

1.   INTRODUCTION

In the process of urban planning and design, a consensus process among a variety of users is required (Innes, 1996). A consensus can therefore be achieved through social and technical constructions which enable unfettered dialogue for understanding, discussing and deliberating (Burgess &

Spangler, 2003; Poplin, 2014). Thus, the understanding of urban design concepts is the most important for achieving consensus. Traditional methods of understanding, discussing and deliberating involves the use of committee meetings and the application of visualization tools to present design alternatives and convey design concepts. An integration of geographic information systems (GIS) with public participatory tools represents one of the latest innovations in this area (Brown & Weber, 2011; Carver et al., 2001). However, these technologies and other map-based applications are frequently criticized as being too complex for the majority of potential users; they often experience difficulty understanding the design concepts (Steinmann, Krek, & Blaschke, 2005). Moreover, different visualization tools were used in different phases of the planning process, and the users need to gather in the same place and at a fixed scheduled time in different phases.

New forms of collaboration and technical solutions emerged during the Web 2.0 era (Poplin, 2012). For example, Google Maps, Google Earth and City Engine can be used by lay users and non-experts without intense training (Jiang et al., 2015; Singh, Jain, & Mandla, 2014). As stated by Wu, He, and Gong (2010), the Internet is undoubtedly the best way of sharing and exchanging urban planning information.

Shen and Kawakami (2010) developed an online visualization tool to attain consensus on townscape design within local planning committees. In this system, participants could select design elements to visualize different alternatives in real time, and experience dynamic scenes of generated virtual townscapes in the Virtual Reality Modelling Language (VRML) world. In their case study, this visualization tool was successful in sharing a common image, and participants were motivated to become involved in deliberation on various aspects of planning and design during committee meetings, and participants could explore from the Internet without spatial and temporal limitations.

Moreover, Gordon, Schirra, and Hollander (2011) proposed that new digital immersive technologies may help users to understand design concepts in the consensus process and move the whole project towards "collaborative rationality". In order to improve the understanding of users with respect to the planning concepts for reaching a consensus, Shen, Kawakami, and Kishimoto (2012) attempted to support planners in presenting their planning concepts during virtual meetings using web-based multimedia materials. Additionally, Vemuri, Poplin, and Monachesi (2014) developed a game that aims to support design concept understanding in a complex urban planning situation. Their study case was taken from India and focused on a very diverse slum area, Dharavi. The complexity emerges due to the variety of different stakeholders' interests and their specific visions about how this area could be developed and renewed.

Despite there being a strong hierarchical administrative system in China, it is found that the consensus process did not work well due to a lack of user interaction interface and efficient information exchange during the top-down planning process, and the difficulties in specifying detailed planning contents. The findings echo the recent experiences in Western countries that emphasize the needs of interaction, negotiation and consensus building in the planning process (Luo & Shen, 2008). VR systems have been used as a tool for understanding design concepts and negotiating design alternatives, to gain consensus (Lorentzen, Kobayashi, & Ito, 2009), and the Internet provides informational services through various devices; it has evolved from an information distribution tool into a network for informational interaction

(Deng et al., 2015). So, the combination of VR technology and the Internet will become a feature of the next era, and provide a broader way for improving urban design concept understanding in the consensus process. However, most online VR platforms have the current limitations of data compression, hardware performance, network bandwidth and costs. Moreover, the Clients need to download the virtual environment and avatar models from the server, and then host on their local computer (Smith, Dodge, & Doyle, 1998). Thus, the virtual environment needs to be compromised of several spatial entities and events, and these entities and events ought to supply an environment in which human activities such as navigation, interaction and communication can be accommodated.

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction (Mell & Grance, 2011). There is no exact definition of Cloud-based VR currently. From a technical point of view, Cloud-based VR is a new technology which combines cloud computing with VR, and provides synchronous transmission and interactive services for large amounts of data, such as video, 3D model data and virtual scenes. In consensus processes, users can employ Cloud-based VR systems in a participative process and Cloud-based VR technology can serve as a software tool for planning to present design concepts and for users to share designs and communicate with each other to reach mutual goals through the Internet (Shen et al., 2014).

Automatic presentation script (APS) in this paper is defined as a technology which can combine different kinds of presentation methods to express urban design alternatives that users can employ to better understand the design concepts and contents.

To address this, in this paper, we will focus on how to improve urban design concept understanding of One Foundation's Disaster Prevention Park in the consensus process, through using Cloud-based VR integrated APS. We will build a Cloud-based VR platform to propose design alternatives and create an APS for auxiliary guidance of users toward understanding the concepts of urban design and deliberating on the design alternatives through the Internet.

The structure of this paper is as follows. In Section 2, we will discuss the research approach in this study. In Section 3, we will present how to build a Cloud-based VR platform that allows users to access the virtual environment to understand design concepts and deliberate on design alternatives through the Internet. In Section 4, we will take a Disaster Prevention Park as a case study, and validate the effectiveness of the Cloud-based VR platform in improving urban design concept understanding in the consensus process. Finally, in Section 5, we will complete the paper with the presentation of conclusions and future work.

2.   RESEARCH APPROACH

Virtual design tools such as 3D modelling and simulation are becoming increasingly sophisticated and integrated. We believe their potential is best realized when they feed into an advanced design process that brings to life the interactions between designers and between each design element. So, in order to promote the use of Cloud-based VR technology for improving urban

design concept understanding in the consensus process, we present a case study of a Disaster Prevention Park planning and design project in southwest China. Our study does not consider details of the park location; the detailed planning considers the functional orientation, architectural design and infrastructure planning of the park. 3D models are created according to the design concepts and design alternatives in a virtual environment.

In this research, we build a Cloud-based VR platform to propose design alternatives, and create an APS for auxiliary guidance of users toward understanding the concepts of urban design in design alternative report meetings, so that the participants, including the users and the designers, can share the common virtual environment, and discuss and solve planning and design problems through the Internet. The designers can easily modify the design alternatives in the virtual environment through calling the 3D model database to insert 3D models, and the users can compare different design alternatives as well as clearly understand the design concepts and eventually reach a consensus in design alternatives.

2.1   Virtual environment design

In virtual environment design, UC-win/Road is a software platform that is used to generate and present a visible and interactive 3D environment. The software can be used for various applications such as in urban planning, traffic simulations and construction demonstrations. The extensive features and visual options allow the formation of detailed virtual demonstrations and presentation and manipulation in real time.

The work of virtual environment design is comprised of three components. First, the terrain data and street map information are imported to create terrain for the virtual environment. In this step, details of the park location are not considered because the users have not yet received land use rights from the government. Second, SketchUp is used to create 3D models that are exported to "*.3d" format which can easily be imported to UC-win/Road, providing the design elements of the 3D model database for the virtual environment design. As a good 3D modelling software, SketchUp successfully unites principles of line drawing with 3D for a bare-bones program that lets designers produce surprisingly complex 3D artwork. Third, the 3D models, including building models, landscape models and infrastructure models are imported, the visual options such as weather and sun position are adjusted, and human agent movements through pre-defined routes are set.

2.2   Design concepts expression

In a sense, the virtual environment will be used as the basic environment to represent the design alternatives. The virtual environment can be observed through the software's interface which is called the "VR-Cloud Client" on the desktop PC of each client. Free navigation in real-time allows the client users to observe the 3D virtual environment from any location and angle. Simulation scenarios are created that help client users to understand the different functions of the Disaster Prevention Park in normal time and in disaster time. An APS is designed to express the design concepts, and express them more clearly. For basic simulations, people act as intelligent agents and obey behavioural characteristics, and vehicles also act as intelligent agents obeying traffic rules. When one person or one car is

controlled by the mouse or keyboard of a client computer, client users can walk or drive freely through a road network or scenario, and a responsive virtual environment enhances the user's sense of presence.

At the heart of consensus is understanding, discussion and deliberation (Susskind, McKearnen, & Thomas-Lamar, 1999). Thus, we will configure a Cloud Server that users can explore, understand and evaluate the design concepts via mouse and keyboard operation, discuss and solve some planning and design problems through the Internet, and achieve consensus on design alternatives.

3. CLOUD-BASED VIRTUAL REALITY PLATFORM

Cloud-based VR is based on UC-win/Road (VR-Cloud Edition) and is used to share 3D virtual content over the network, whether on an office Land Area Network (LAN) or on the Internet. Clients who access the content are able to navigate through the virtual environment using basic UC-win/Road navigation modes (free, travel, driving and so on). The global parameters of the virtual environment such as the time of the day and the weather can also be configured by the clients. Cloud-based VR also provides cloud-based collaboration features. Users can create graphical annotations at any location in the virtual environment to provide better understanding of the modelled environment. Clients can also discuss using 3D forums. They can create new discussions or reply to discussions of other users.

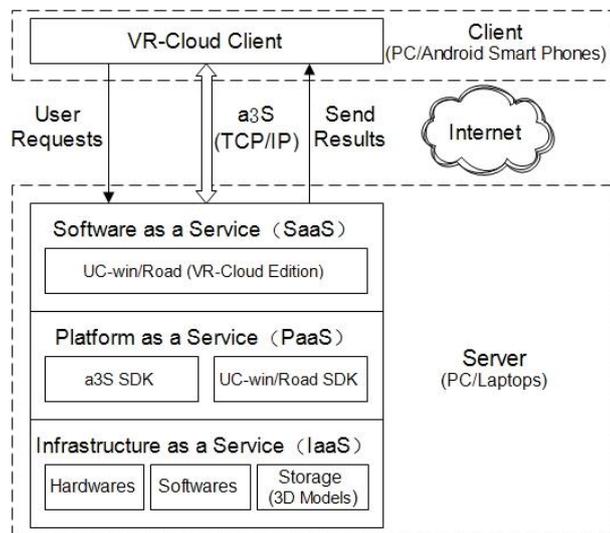## 3.1 The framework of Cloud-based Virtual Reality

Figure 1. The framework of Cloud-based VR Platform

The framework of the Cloud-based VR Platform is shown in *Figure 1*. This platform has a central server which contains the data for the virtual environment, a range of avatar models and also acts as the communications hub for understanding and online discussion. The individual participants have a "Client" on their local computer which provides the tools to view and move through the virtual environment and to also discuss or communicate

via a dialogue box in which one would type comments visible to other users. "Client" software can be downloaded from the website for free and connects with the server through the Internet.

In this framework, a suitable server (a3S), or hosting device, is anything that hosts multimedia cloud technology that allows high quality video and audio to be supported and streamed between the server and client application, as well as the high-speed transmission of large-capacity data (Ito et al., 2013). a3S can connect the core parts controlling Transmission Control Protocols (TCP), the server and each client. It also controls commands, and manages the synchronization and authorization system.

3.2   The working process of Cloud Server

The working process of the Cloud Server is shown in *Figure 2*. There are six steps in this process, including loading terrain data and the street map, creating (or modifying) and importing 3D models for the design alternatives, creating a virtual environment (VE), creating simulation scenarios and APS, exploring or evaluating the design and configuring the Cloud Server.
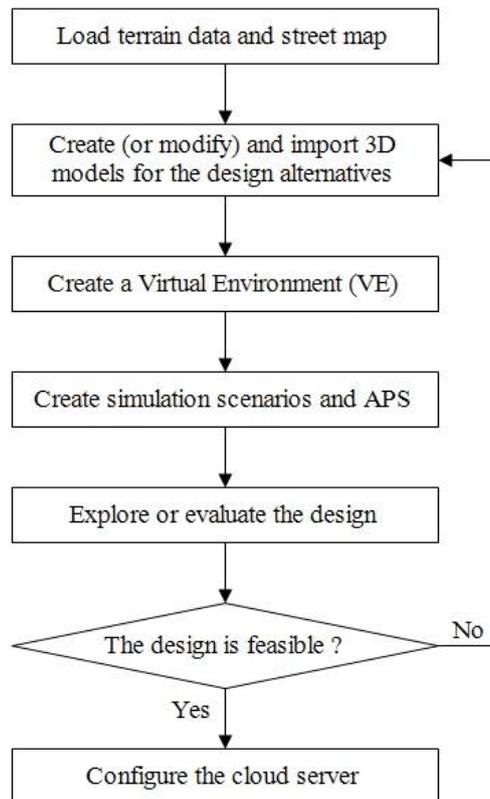

Figure 2. The working process of Cloud Server

According to the requirements of the design program, One Foundation (the Park owner) wanted to construct a disaster prevention park inside the Bei San Huan Road in Chengdu City, of Sichuan Province. Furthermore, some scholars have pointed out the lack of a disaster prevention park system in Chengdu City after the occurrence of the 5.12 Wenchuan earthquake, and analyzed the actual situation of Chengdu City. They have considered its urban population density distribution, transport distribution and disaster prevention park, probed into the planning and design of the city's disaster prevention park, and believe that a new disaster prevention park should be

considered for the area inside the Bei San Huan Road ([Tian et al., 2010](#)).
Therefore, the terrain data of China is uploaded and the street map of the
area inside of Bei San Huan Road in Chengdu City is imported, as shown in
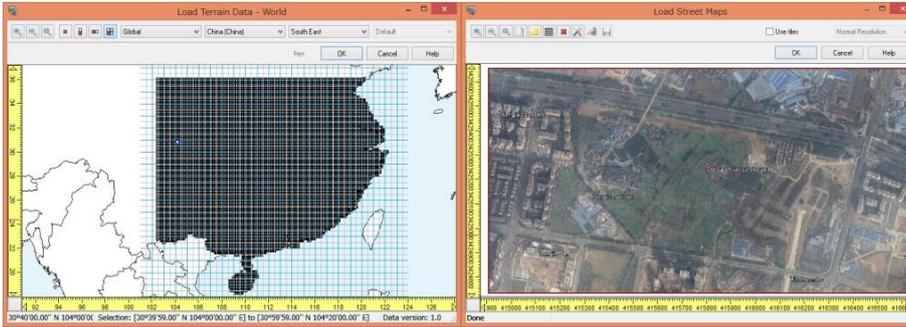*Figure 3*.

Figure 3. Load terrain data and street map

In order to create a virtual environment, the basic work required is to
create 3D models for the design alternatives. Currently, there are many kinds
of modelling software, such as 3DS Max, SketchUp and Maya, which are
often used in urban planning and design. Due to the easy operating and
compatibility of SketchUp, we used SketchUp to create different kinds of 3D
models and imported these to UC-win/Road (VR-Cloud Edition), comprising
the 3D model database for creating the virtual environment. We created
building models, landscape models and infrastructure models, such as tents,
communications facilities, water tanks and photovoltaic modules, which are
necessary in the aftermath of disasters. *Figure 4* shows one of the landscape
models which was created using SketchUp for One Foundation's disaster
prevention park, and *Figure 5* shows the virtual environment of design
alternatives after importing the 3D object models.
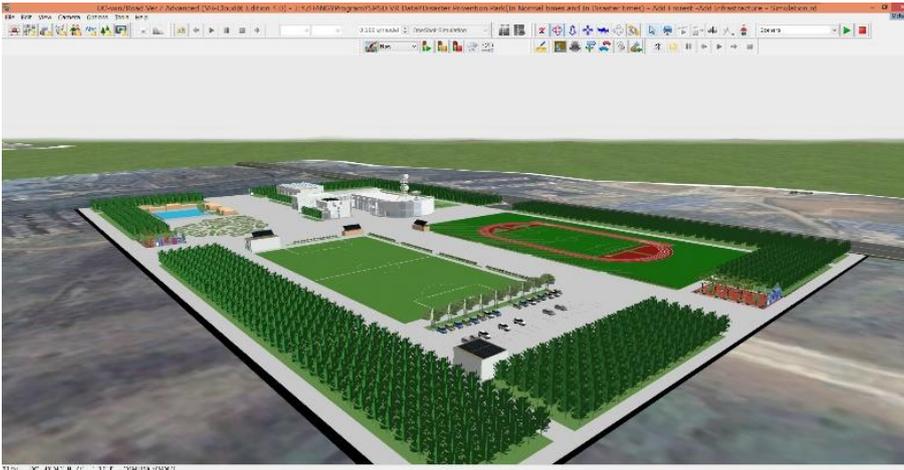

Figure 4. 3D modelling in SketchUp

Figure 5. The virtual environment of design alternatives

Simulation scenarios provide a dynamic virtual environment for online discussion so that users can better understand the design alternatives. In this paper, we try to set the human behaviours as connected with the function of a Disaster Prevention Park, in normal times and in disaster times, through setting scripts. Moreover, an APS is created for auxiliary guidance of users toward understanding the design concepts. *Figure 6* shows the simulation scenario of the playground during normal use, and *Figure 7* illustrates the APS of One Foundation's Disaster Prevention Park and its running result.
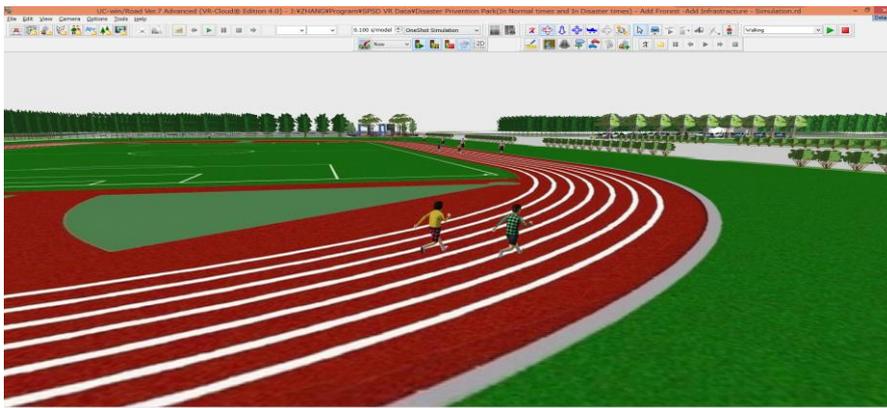

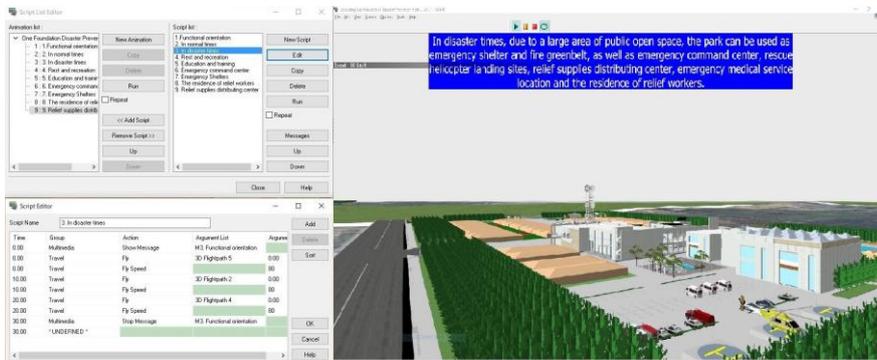*Figure 6.* Simulation scenario of playground in normal times

Figure 7. APS of One Foundation's Disaster Prevention Park and its running result

4. CASE STUDY: ONE FOUNDATION'S DISASTER PREVENTION PARK

As an important part of sustainable urban development, disaster prevention and mitigation is a significant step toward achieving sustainable economic and social development. One Foundation is a Non-Governmental Organization (NGO), which plays an important role in disaster prevention and mitigation in China. However, due to the lack of an independent command system, as well as a clear disaster management system in disaster times, some problems have resulted, such as confusion amongst personnel management and low efficiency of relief supplies' distribution when the NGO responds to natural disasters. Moreover, there are no permanent establishments for disaster management; it is difficult for the NGO to carry out disaster prevention education and volunteer training work in normal times, as "supplementary" to that of government. Therefore, they wanted to build a disaster prevention park which integrated the functions of education and training, earthquake experience, emergency command, evacuation and rescue, in Chengdu City, China.

4.1 Functional orientation of Disaster Prevention Park

One Foundation's Disaster Prevention Park covers an area of 160 acres, its functional orientation drawing on international experience, especially the construction experience of Disaster Prevention Parks in Japan. The functional orientation of a Disaster Prevention Park is divided between its normal times' function and disaster times' function. In normal times, the park has two main functions: social culture function and environmental protection, where social culture function includes rest and recreation, spiritual civilization and disaster prevention education, such as through outdoor recreation, sports, dissemination of scientific knowledge, disaster prevention training and so on; and environmental protection mainly embodies the maintenance of ecological balance and beautification of the urban landscapes, such as through erosion control, fresh air provision, relieving of heat island effect and so on. In disaster times, due to it being a large area of public open space, the park can be used as an emergency shelter and fire greenbelt, as well as an emergency command centre, for rescue helicopter landing sites, relief supplies distribution centre, emergency medical service location and the residence of relief workers. The functional orientation and support facilities of One Foundation's Disaster Prevention Park are shown in *Table 1*.

Table 1. The functional orientation and support facilities of Disaster Prevention Park

Time	Main function	Support facilities
In normal times	Rest and recreation	Playground, leisure square, landscape and make green by planting trees, flowers, etc.
	Education and training	Classrooms, relief exhibition hall, disaster prevention training centre, earthquake experience room, reading room, etc.
	Daily operations	The park management office, relief product exhibition hall, sales department, catering centre, accommodation centre, etc.
In dis	Emergency command	Information summary room, commander room,

Time	Main function	Support facilities
	centre	lounge, office equipment, communications equipment, emergency medical service location, etc.
	Emergency shelters	Emergency tent dormitory, emergency water supply facilities, emergency toilets and bathing facilities, emergency power supply facilities, emergency sewage system, etc.
	The residence of relief workers and relief supplies distribution centre	Relief supplies reserve and distribution centre, parking, rescue helicopter landing sites, accommodation centre, etc.

4.2 Design concept understanding and design alternatives evaluation in consensus process

In order to validate the effectiveness of the Cloud-based VR platform in improving urban design concept understanding in consensus building, we have applied this platform to express the design alternatives and design concepts in design alternative report meetings, and tried to convey our design concepts to the users and other people who were interested in this project. The APS is run first so that users can better understand the design concepts as shown in *Figure 7*, then the design alternatives were discussed and modified in a virtual environment based on the Cloud-based VR platform, and eventually a consensus was reached on the design alternatives. *Figure 8* shows the working process of consensus building in a design report meeting.
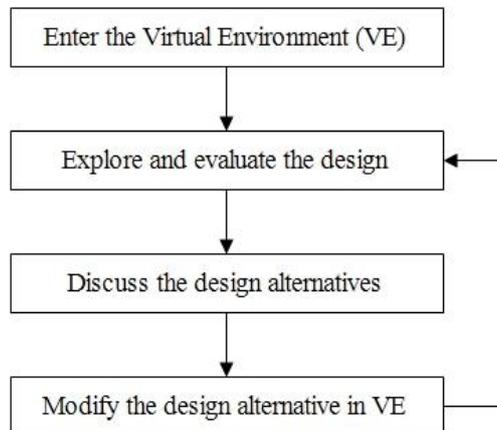

Figure 8. The working process of consensus building in design alternatives report meeting

The users can enter the virtual environment through VR-Cloud Client which is client software that can be downloaded from the website for free, and connects with the Cloud Server through the Internet. Users can input the server's IP address to connect with the Cloud Server, and then enter the virtual environment, as is shown in *Figure 9*.
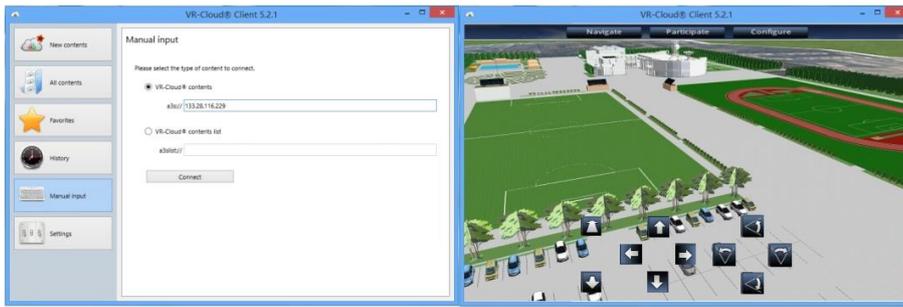
Figure 9. Enter the virtual environment

In the design alternatives report meeting, the Disaster Prevention Park is discussed with the users, from functional orientation to overall layout, to infrastructure planning. For this paper, we focused on the architectural design of the Disaster Management Centre and the infrastructure planning of the park since these two parts are the core content of the construction of the Disaster Prevention Park, and the following section focuses on these two aspects to conduct a discussion.

4.2.1 Architectural design of Disaster Management Centre

Based on the functional orientation of One Foundation's Disaster Prevention Park, and combined with the construction experience of Disaster Prevention Parks in Japan, the Disaster Management Centre is responsible for disaster prevention education, training and daily operations in normal times, and in disaster times, its main functions being as an emergency shelter and fire greenbelt, as well as emergency command centre, rescue helicopter landing sites, relief supplies distribution centre, emergency medical service location, the residence of relief workers and so on. According to the "Design Code of Office Building" (JGJ67-2006), the average office space per person should be not less than $4m^2$ (MOC, 2006), and the "Emergency shelter for earthquake disasters--site and its facilities" (GB 21734-2008) requires the construction area of a Disaster Management Centre of a Disaster Prevention Park should be more than $2000m^2$ (SAC, 2008). Therefore, for the first alternatives of the Disaster Management Centre's architectural design, the building of a Disaster Management Centre consisted of two parts: the main building and the Disaster Experience Hall, with a total construction area of $5000m^2$. Since the Disaster Experience Hall needs an MTS shake table to support seismic experience, and in order to avoid affecting the main building, it is important to separate the two parts, and maintain one part as a single building; the Disaster Experience Hall has two stories, and the main building has three stories.

The users considered their actual needs for disaster prevention in southwest of China, and discussed the architectural design of the Disaster Management Centre in detail with us, and put forward some suggestions. First of all, taking into account the reserve and distribution of relief supplies, it is best to separate the Relief Supplies Reserve and Distribution Centre from the main building. What's more, the height of all buildings should not exceed 8 meters or two stories, in order to better achieve the purpose of disaster prevention. Last, but not least, besides the Disaster Management Centre, there are Disaster Prevention Schools within the locality, and they provide formal education, so the Disaster Management Centre should take full account of the function of rescue training.

During the discussion, we modified the first alternatives in the virtual environment considering the suggestions of the users, and proposed the second alternatives. The functional planning of the Disaster Management Centre in two alternatives and the 3D effect drawing of the Disaster Management Centre with the two alternatives were as shown in *Figure 10* and *Figure 11* respectively, and a consensus was eventually reached on the second alternatives.
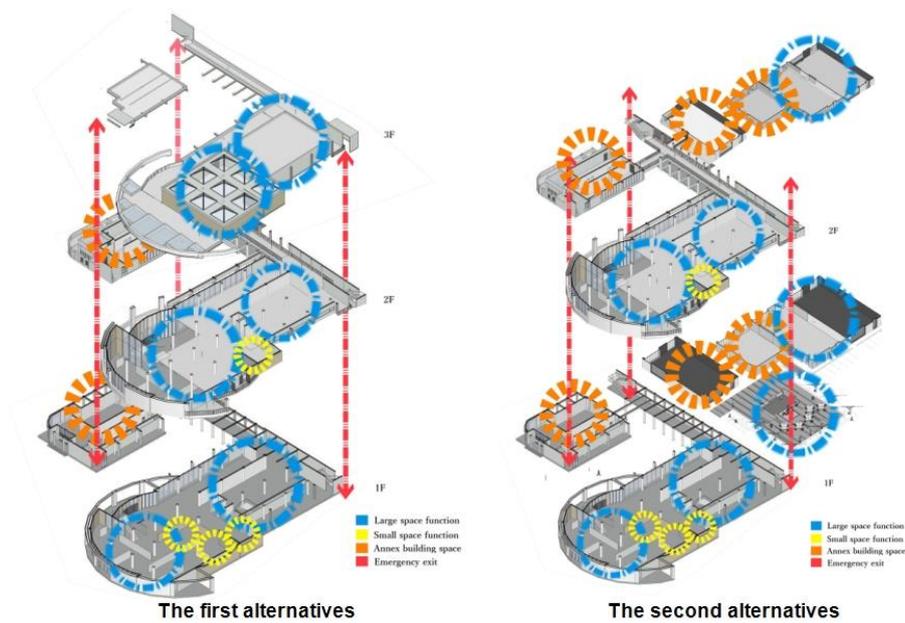

Figure 10. Functional planning of Disaster Management Centre in two alternatives
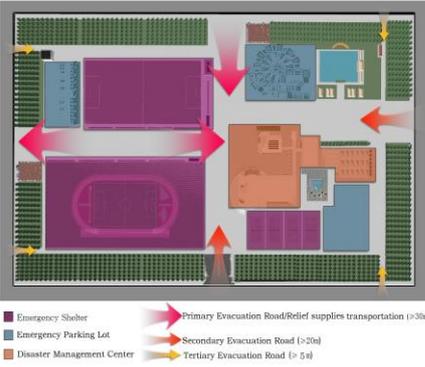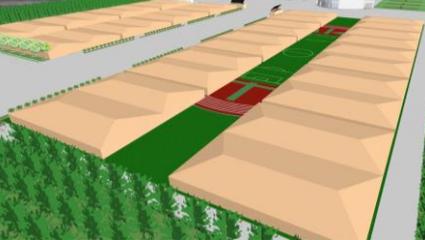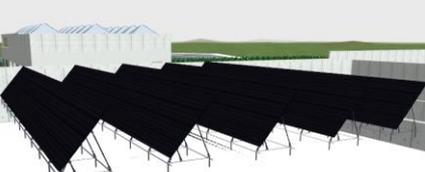

Figure 11. 3D effect drawing of Disaster Management Centre in two alternatives

4.2.2   Infrastructure planning of Disaster Prevention Park

The infrastructure of the Disaster Prevention Park includes an evacuation road, emergency shelter, greenbelt, emergency water supply, emergency power supply, emergency communication infrastructure and so on. The infrastructure of One Foundation's Disaster Prevention Park was planned and designed based on China's "Emergency shelter for earthquake disasters-site and its facilities" standard (GB 21734-2008), as shown in *Table 2*.

Table 2. Infrastructure planning of One Foundation's Disaster Prevention Park

Infrastructure	Main functions and requirements	3D presentation in virtual environment
Evacuation Road	Evacuation road connection with all emergency shelters and the Disaster Management Centre, to ensure the roads are kept unblocked and effective for evacuation and relief supplies' transportation. The evacuation roads around the emergency shelters should be more than two lanes, and the width should be more than 5m.	
Emergency Shelter	Emergency Shelter is the place for people to live temporarily when they cannot live in their previous residence, and the average area per person in emergency shelter should be more than 2m².	
Greenbelt	Greenbelt is used for isolating traffic noise, maintaining ecological balance and beautifies the urban landscape in normal times, while used for isolating fire to prevent a secondary disaster after an earthquake. It surrounds the park and the width is 25m.	
Emergency Water Supply	Emergency water supply, including swimming pool and water tank. In disaster times, the water stored in the swimming pool can be used for bathing, washing and flushing toilets, while the water tank can provide drinking water for initial three day survival period.	
Emergency Power Supply	Emergency power supply, including solar photovoltaic system and mini dynamotors, that can provide power for living, medical treatment and communication in disaster times.	
Emergency Communication Infrastructure	Emergency Communication Infrastructure can be used for contact with the outside world when wirelines, cell phones and other conventional means of communication fail in disaster times.	
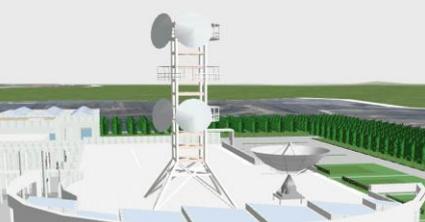
In the virtual environment, the users viewed the design alternatives according to our design concept, and discussed the infrastructure planning with enthusiasm. In the initial design, toilets and bathing facilities were considered near the swimming pool, located in the northwest of the park, and inside the Disaster Management Centre. The users believed that besides the refugees, there may be other local people who come to use toilets and bathing facilities due to the taps running dry after an earthquake. As a result, they advised increasing the allocation of emergency toilets and bathing facilities in the infrastructure planning, and these facilities will not affect the park in normal times as far as possible.
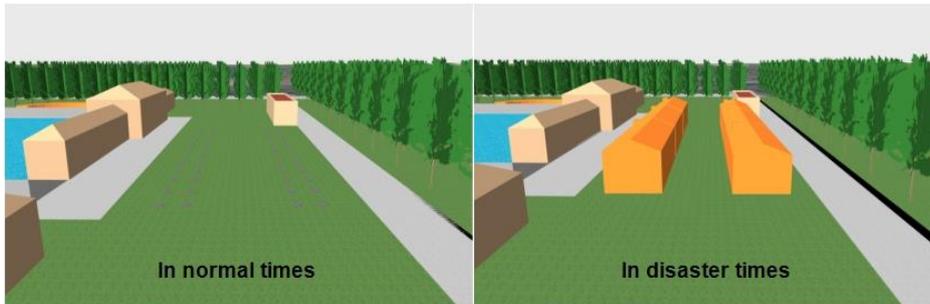

Figure 12. Emergency toilets and bathing facilities

In order not to affect the landscape of the park in normal times, we considered using underground septic tanks, covered with lawn and keeping reserved sewage covers on the ground. There is green lawn in normal times and it is easy to change to emergency toilets and bathing facilities when setting up mobile housing or tents in disaster times. *Figure 12* shows the planning of emergency toilets and bathing facilities in the Disaster Prevention Park.

5.   CONCLUSION AND FUTURE WORK

VR combined with cloud computing provides advanced information technology, and its application to urban planning and design is a challenging topic. Cloud-based VR integrated with an APS as we proposed in this paper can clearly express design alternatives and design concepts, effectively solving the problem of miscommunication in the process of design concepts transfer and design alternatives discussion in urban planning and design, and enabling the eventual reaching of a consensus on the design concepts and design alternatives, promoting the feasibility and real-time of urban design, saving discussion time for a design project, and improving design efficiency.

However, there are still some deficiencies existing in Cloud-based VR platforms. For example, although 3D models in the virtual environment can be directly edited, its editing functions are just scaling, rotating and other simple operations; as for complex editing, such as structural adjustment or material replacement, this needs to be edited in SketchUp and then imported to UC-win/Road. Therefore, future work will focus on improving the functions of 3D model editing in the virtual environment.

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