Volume 5, No. 1 (2017)

International Review for Spatial Planning and Sustainable Development

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For investigation regarding the impact of planning policy on spatial planning implementation, International Community of Spatial Planning and Sustainable Development (SPSD) seeks to learn from researchers in an integrated multidisciplinary platform that reflects a variety of perspectives—such as economic development, social equality, and ecological protection—with a view to achieving a sustainable urban form.

This international journal attempts to provide insights into the achievement of a sustainable urban form, through spatial planning and implementation; here, we focus on planning experiences at the levels of local cities and some metropolitan areas in the world, particularly in Asian countries. Submissions are expected from multidisciplinary viewpoints encompassing land-use patterns, housing development, transportation, green design, and agricultural and ecological systems.

IRSPSD INTERNATIONAL
ISSN 2187-3666 (Online)

International Review for Spatial Planning and Sustainable Development
https://www.jstage.jst.go.jp/browse/irspsd
http://spsdpress.jimdo.com/volumes/
http://dspace.lib.kanazawa-u.ac.jp/dspace/bulletin/irspsd

International Review for Spatial Planning and Sustainable Development

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International Review for Spatial Planning and Sustainable Development, Volume 5 No.1, 2017

Content

International review for spatial planning and sustainable development, Vol.5 No.1 (2017), 1-3
ISSN: 2187-3666 (online)
DOI: http://dx.doi.org/10.14246/irspsd.5.1_1

Editorial Introduction

Special Issue on "BIM and VR Technology"

Guest Editors:

Yuanyi Zhang[1*] and JenTe Pai[2]
1 School of Architecture, Fuzhou University
2 Department of Land Economics , National Chengchi University
** Corresponding Author, Email: zyye@fzu.edu.cn*

During the process of urban planning and design, it is important that all stakeholders understand, participate, communicate and collaborate with each other to obtain a high quality outcome. However, communication difficulties mainly occur as a result of different planning cultures, and because there is insufficient collaboration and information sharing during the process. The most common problem is that the information is not presented in such a way that people can understand it. Building Information Modeling (BIM) is becoming a better known established collaboration process that stakeholders can better understand, communicate and make decisions with in urban planning and design (Hergunsel, 2011). In addition, the use of Virtual Reality (VR) technology as a tool for collaboration to exchange information and data has increased significantly (Menck, Weidig, & Aurich, 2013). Thus, this special issue focuses on BIM and VR technologies which play more and more important roles in urban planning and design.

As stated by Kim (2004), any 3D visualization method typically involves 3D modeling, so the first paper "Automatic Generation of 3D Building Models with Efficient Solar Photovoltaic Generation" aims to contribute an automatic modeling system which integrates Geographic Information Systems (GIS) with Computer Graphics (CG) to automatically generate 3D building models based on building polygons or building footprints on digital maps (Sugihara & Shen, 2017). The proposed system partitions orthogonal building polygons into a set of rectangles and places rectangular roofs and box-shaped building bodies on these rectangles. To implement efficient PV generation, the authors propose to automatically generate 3D building models topped with double shed roofs overlaid by PV arrays, and simulate the solar photovoltaic generation change of a city block by performing land readjustment and changing the shape of buildings, ordinary roofed houses or double shed roofed houses suitable for efficient PV generation. Their simulation result reveals that double shed roofed houses have greatly improved solar photovoltaic generation.

The second paper "Construction of Urban Design Support System using Cloud Computing Type Virtual Reality and Case Study" contributes an urban design support system (UDSS) of Cloud-based virtual reality (Cloud-based VR) for urban planning and urban design (Lei et al., 2017). The authors introduce a Cloud-based virtual reality platform (VR-Cloud server) which can be used to open the VR dataset to public collaboration over the Internet. The digital asset representing the design scheme of design concepts includes the Land Use Zone, Building Regulations, Urban Design Style, and other Design Detail of urban planning and design. The authors also gave three latest case studies of how a Cloud-based VR has affected the urban planning and design process in each project, and attempted to argue what exactly has been altered during each planning phase, based on the qualitative findings taken from the three cases.

Consensus building is a conflict-resolution process used mainly to settle complex, multiparty disputes (Burgess & Spangler, 2003). A consensus process among a variety of stakeholders is required during the process of urban planning and design. So, the third paper "Cloud-based Virtual Reality Integrated Automatic Presentation Script for Understanding Urban Design Concepts in the Consensus Process" focuses on how to improve the understanding of design concepts related to the One Foundation Disaster Prevention Park of China through a consensus process using a Cloud-based VR integrated automatic presentation script (APS) (Zhang et al., 2017). The authors built a Cloud-based VR platform to propose design concepts, and created an APS for auxiliary guiding of users toward understanding the concepts of urban design and deliberate design alternatives in a design report meeting via the Internet. Their application results show that the Cloud-based VR (with integrated APS) platform not only can simplify the discussion of design concepts without the limitation of space and time, but can also improve the efficiency of design alternative discussions to reach a consensus without any extra expense.

In recent years, BIM technology has usually been used as a design evaluation tool to consider the relationship between indicators concerning the urban landscape view planning, physical spatial design and the performance of environmental planning (Lee et al., 2010). In order to foster better, but also speedy, decision-making processes, the fourth paper "Assessment of the Process of Designing an Apartment Building through IM and VR" applied various types of software and solutions based on Information Modeling (IM) and VR in the design of a company dormitory (Imaizumi, 2017). In this research, simulations via a BIM model are performed and a Cloud-based 3D VR is used for consensus building. The author examines the detailed process of the application project, the effectiveness of feedback on the design, and the process of reaching consensus. In addition to what has been done or is currently available, the author also suggested a summary of what the research team will offer in the future in terms of BIM modeling, environment simulation and VR simulation, collectively.

Vertical greening means a vertical triumph of greenery in high density urban areas, the use of vertical greening in urban areas to improve sustainability of the environment. However, conventional vertical greening is in open fields, unprotected and threatened by climate disasters. A greenhouse system could instead solve different facets of these problems. Therefore, the final paper "Green-energy water-autonomous greenhouse system: an alternative-technology approach towards sustainable smart-green vertical greening in smart cities" summarizes new greenhouse technologies and approaches to introduce the relationship and development between vertical greening and greenhouse systems, and presents a proposed novel prototype of a green-energy water-autonomous greenhouse system (Hung & Peng, 2017). The authors suggest using a true BIM model for further design of the proposed greenhouse system. A design with foresight based on BIM modeling is necessary to provide advanced understanding of the proposed greenhouse system and to allow us to build a smart-green point cloud with BIM workflow for any network in a smart city.

This special issue is one of the outputs of the Biennial International Conference on Spatial Planning and Sustainable Development held on 7-9 August in 2015 at the Taipei University of Technology. We would like to express our sincere gratitude to the researchers who joined the conference and submitted their works to our journal. Special thanks go to Prof. Kuang-Hui Peng who organized this International Conference as the Chairman of SPSD2015. We would also like to express our sincere gratitude to the reviewers who gave us their most generous support on reading and commenting on the papers. We hope all our efforts will contribute to the development of urban planning and design, as well as the creation of a more sustainable world.

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International review for spatial planning and sustainable development, Vol.5 No.1 (2017), 4-14
ISSN: 2187-3666 (online)
DOI: http://dx.doi.org/10.14246/irspsd.5.1_4

Automatic Generation of 3D Building Models with Efficient Solar Photovoltaic Generation

Kenichi Sugihara[1*] and Zhenjiang Shen[2]
1 School of Information Media, Gifu Keizai University
2 School of EnvironmentalDesign, Kanazawa University
** Corresponding Author, Email: sugihara@gifu-keizai.ac.jp*

Received: January 05, 2016; Accepted: September 30, 2016

Key words: 3D building model, automatic generation, solar photovoltaic generation, 3D city model

Abstract: To facilitate public involvement for sustainable development, 3D models simulating real or near future cities using 3D Computer Graphics (CG) can be of great use. 3D city models are important in environmentally friendly urban planning that will use solar photovoltaic (PV) generation. However, enormous time and labour has to be consumed to create these 3D models using 3D modelling software such as 3ds Max or SketchUp. In order to automate laborious steps, this paper proposes a Geographic Information System (GIS) and CG integrated system that automatically generates 3D building models based on building polygons or building footprints on digital maps, which show most building polygons' edges meet at right angles (orthogonal polygon). A complicated orthogonal polygon can be partitioned into a set of rectangles. The proposed integrated system partitions orthogonal building polygons into a set of rectangles and places rectangular roofs and box-shaped building bodies onto these rectangles. In this paper, for placing solar panels on a hipped roof, the structure of an ordinary hipped roof that is made up of two triangular roof boards and two trapezoidal ones is clarified. To implement efficient PV generation, this paper proposes to automatically generate 3D building models for buildings topped with double shed roofs with overlaid PV arrays. The sizes and positions, slopes of roof boards and main under roof constructions are made clear by presenting a top view and side view of a double shed roof house. For the applied example of the developed system, this papers presents a simulation of the solar photovoltaic generation change of a city block by performing land readjustment and changing the shape of buildings, ordinarily roofed houses or double shed roofed houses suitable for efficient PV generation. Our simulation reveals that double shed roofed houses have greatly improved solar photovoltaic generation.

1. INTRODUCTION

A 3D city model such as the one shown in *Figure 1* is important in urban planning and gaming industries. Urban planners may then draw maps for sustainable development. 3D city models based on these maps are quite effective in understanding what occurs if this alternative plan is realized. To facilitate public involvement for sustainable development, 3D models simulating real or near future cities by 3D Computer Graphics (CG) can be of great use. 3D city models are important in environmentally friendly urban planning that will use solar photovoltaic (PV) generation. However, enormous time and labour has to be consumed to create these 3D models, using 3D modelling software such as 3ds Max or SketchUp. For example, when manually modelling a house with roofs by Constructive Solid Geometry (CSG), one must use the following laborious steps:

(1) Generation of primitives of appropriate size, such as box, prism or polyhedron that will form parts of a house, **(2)** Boolean operations are applied to these primitives to form the shapes of parts of a house, such as making holes in a building body for doors and windows, **(3)** Rotation of parts of a house, **(4)** Positioning of parts of a house, and (5) Texture mapping onto these parts.

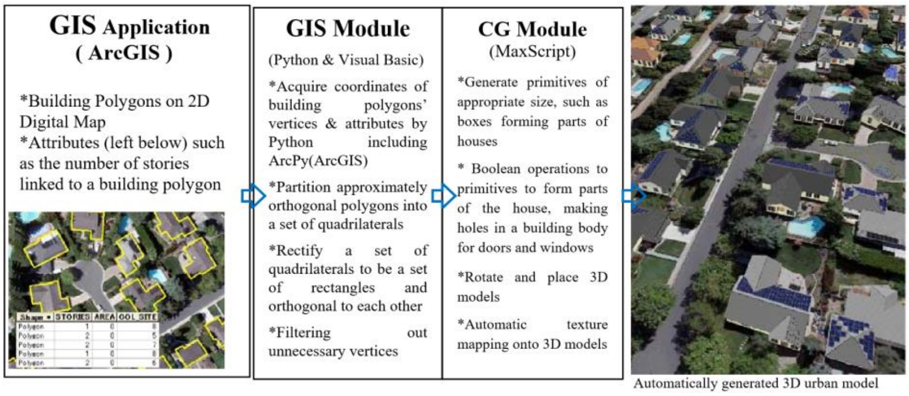


Figure 1. Pipeline of Automatic Generation for 3D Building Models

In order to automate laborious steps, this research proposes a GIS and CG integrated system for automatically generating 3D building models (Sugihara & Kikata, 2012) based on building polygons or building footprints on a digital map, as shown in *Figure 1 Left*, which shows most buildings' polygon edges meet at right angles (orthogonal polygons). A complicated orthogonal polygon can be partitioned into a set of rectangles. The proposed integrated system partitions orthogonal building polygons into a set of rectangles and places rectangular roofs and box-shaped building bodies onto these rectangles. In order to partition an orthogonal polygon, the research also proposes a useful polygon expression (RL expression: an edge's Right & Left turns expression) and a partitioning scheme for deciding from which vertex a dividing line (DL) is drawn (Sugihara, 2009).

Since technicians are drawing building polygons manually with digitizers, depending on aerial photos or satellite imagery as shown in *Figure 1 Left*, not all building polygons are precisely orthogonal. When placing a set of boxes as building bodies for forming the buildings, there may be gaps or overlaps between these boxes if the building polygons are not strictly orthogonal. In the integrated system, the GIS module rectifies the shape of building polygons and creates a set of mutually orthogonal rectangles without any gap or overlap.

In this paper, to place solar panels on the roof for efficient solar photovoltaic (PV) generation, the structure of an ordinary hipped roof that is made up of two triangular roof boards and two trapezoidal ones is clarified. To implement efficient PV generation, this paper proposes to automatically generate 3D building models topped with double shed roofs with overlaid PV arrays. The sizes and positions, slopes of roof boards and main under roof constructions are made clear by designing a top view and side view of a double shed roofed house. For the applied example of the developed system, this research simulates the solar photovoltaic generation change of a city block by performing land readjustment and changing the shape of buildings, i.e., ordinary roofed houses or double shed roofed houses suitable for efficient PV generation. This simulation reveals that double shed roofed houses have greatly improved solar photovoltaic generation.

2. RELATED WORK

Since 3D urban models are important information infrastructure that can be utilized in several fields, researches on the creation of 3D urban models are in full swing. Various types of technologies, ranging from computer vision, computer graphics, photogrammetry to remote sensing, have been proposed and developed for creating 3D urban models.

Procedural modelling is an effective technique to create 3D models from sets of rules such as L-systems, fractals, and generative modelling language (Parish & Müller, 2001). Müller et al. (2006) have created an archaeological site of Pompeii and a suburban model of Beverly Hills by using a shape grammar that provides a computational approach to the generation of designs. They import data from a GIS database and try to classify imported mass models as basic shapes in their shape vocabulary. If this is not possible, they use a general extruded footprint together with a general roof obtained by the straight skeleton computation defined by a continuous shrinking process (Aichholzer et al., 1995). By using the straight skeleton, Kelly and Wonka (2011) present a user interface for the exterior of architectural models to interactively specify procedural extrusions, a sweep plane algorithm which computes a two-manifold architectural surface.

Image-based capturing and rendering techniques, together with procedural modelling approaches, have been developed that allow buildings to be quickly generated and rendered realistically at interactive rates. Bekins and Aliaga (2005) exploit building features taken from real-world capture scenes. Their interactive system subdivides and groups the features into feature regions that can be rearranged to texturize a new model in the style of the original. The redundancy found in architecture is used to derive procedural rules describing the organization of the original building, which can then be used to automate the subdivision and texturing of a new building. This redundancy can also be used to automatically fill occluded and poorly sampled areas of the image set.

Aliaga, Rosen, and Bekins (2007) extend the technique to inverse procedural modelling of buildings and they describe how to use an extracted repertoire of building grammars to facilitate the visualization and modification of architectural structures. They present an interactive system that enables both creating new buildings in the style of others and modifying existing buildings in a quick manner.

Vanegas, Aliaga, and Beneš (2010) interactively reconstruct 3D building models with the grammar for representing changes in building geometry that approximately follow the Manhattan-world (MW) assumption which states there is a predominance of three mutually orthogonal directions in the scene. They say automatic approaches using laser-scans or LIDAR data, combined with aerial imagery or ground-level images, suffer from one or all of low-resolution sampling, robustness and missing surfaces. One way to improve quality or automation is to incorporate assumptions about the buildings such as the MW assumption.

By these interactive modelling systems, 3D building models with plausible detailed façades can be achieved. However, the limitation of these modelling systems is the large amount of user interaction involved (Jiang, Tan, & Cheong, 2009). When creating 3D urban models for urban planning or facilitating public involvement, 3D urban models should cover a lot of involved citizens' and stakeholders' buildings. This means that it will take enormous time and labour to model a 3D urban model with hundreds of buildings. Thus, a GIS and CG integrated system that automatically generates 3D urban models immediately is proposed, and the generated 3D building models that constitute 3D urban models are approximate geometric 3D building models that citizens and stakeholders can recognize as their future residence or real-world buildings.

Xiao and Furukawa (2014) present a 3D reconstruction and visualization system to automatically produce clean and well-regularized texture-mapped 3D models for large indoor scenes from ground-level photographs and 3D laser points. The key component is a new algorithm called "Inverse CSG" for reconstructing a scene in a Constructive Solid Geometry (CSG) representation consisting of volumetric primitives, which imposes regularization constraints to exploit structural regularities. However, with the lack of ground-truth data preventing them from conducting quantitative reconstruction accuracy evaluations, they have to manually overlay their model with a floor plan image.

This computer vision methodology, together with following the Manhattan-world (MW) assumption (Vanegas, Aliaga, & Beneš, 2010), uses 3D point clouds from laser-scans, extracting line segments passing through them by the Hough transformation for structural regularities. In the approach presented in this paper, only the position of the vertices of a building polygon is used for structural regularities or rectification, which reduces the heavy burden of dealing with a huge amount of 3D point cloud data.

3. PIPELINE OF AUTOMATIC GENERATION

As shown in *Figure 1*, the proposed automatic building generation system consists of the GIS application (ArcGIS, ESRI Inc.), GIS module and CG module. The source of the 3D urban model is a digital residential map that contains building polygons linked with attribute data shown in *Figure 1*, consisting of the number of storeys, the image code of the roof, wall and the type of roof (gable roof, hipped roof, gambrel roof, mansard roof, temple roof and so forth). The maps are then pre-processed within the GIS module, and the CG module finally generates the 3D urban model. As a GIS module, a Python program including ArcPy (ArcGIS) acquires coordinates of the building polygons' vertices and attributes.

Pre-processing within the GIS module includes the procedures as follows: **(1)** Filter out any unnecessary vertex whose internal angle is almost 180 degrees, **(2)** Partition or separate approximately orthogonal polygons into a set of quadrilaterals, **(3)** Generate inside contours by straight skeleton computation for placing doors, windows, fences and shop façades which are setback from the original building polygon, **(4)** Rectify a set of quadrilaterals to be a set of rectangles and orthogonal to each other, **(5)** Export the coordinates of polygons' vertices, the length, width and height of the partitioned rectangle, and attributes of the buildings.

The CG module receives the pre-processed data that the GIS module exports, generating 3D building models. In the GIS module, the system measures the length and inclination of the edges of the partitioned rectangle. The CG module generates a box of the length and width measured in the GIS module.

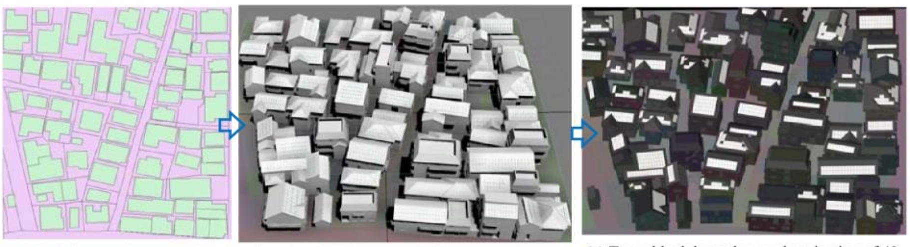
In the case of modelling a building with roofs, the CG module follows these steps: **(1)** Generate primitives of appropriate size, such as boxes, prisms or polyhedra, that will form the various parts of the house, **(2)** Boolean operations are applied to these primitives to form the shapes of parts of the house, for example, making holes in a building body for doors and windows, making trapezoidal roof boards for a hipped roof or a temple roof, **(3)** Rotate parts of the house according to the inclination of the partitioned rectangle, **(4)** Place parts of the house, **(5)** Map texture onto these parts according to the attribute received, **(6)** Copy the 2nd floor to form the 3rd floor or more in case of buildings higher than three stories.

The length and width of a box as a house body are decided by the rectangle partitioned or separated from a building polygon in the GIS module. Also, the length of a thin box as a roof board is decided by the rectangle partitioned while the width of a roof board is decided by the slope of the roof given as a parameter. The CG module has been developed using Maxscript that controls 3D CG software (for example, 3ds MAX, Autodesk Inc).

4. 3D BUILDING MODEL FOR EFFICIENT SOLAR PHOTOVOLTAIC (PV) GENERATION

4.1 3D Model of Town Block and the Display of Solar PV Generation Area

Generated power of solar photovoltaic (PV) panels depends on the intensity of the sunlight and the installation condition of the panels such as the panels' azimuth, pitch, surrounding environment, atmospheric temperature, and its location. The data map for the amount of sunshine is made and well maintained by the New Energy and Industrial Technology Development Organization (NEDO) of Japan. In the map, by indicating where the installation of the panels is, the amount of sunshine is then given.



(a) Digital map of town block (b) Town block automatically generated (c) Town block by orthogonal projection of 43 degrees depression angle

Figure 2. 3D town block model automatically generated and imaged by orthogonal projection

Figure 2 shows the flow of automatic generation from a digital map of a town block to a 3D model of a town block, and an orthogonal projection image with 43 degree depression angle. In the town block model, 3D building models have south and east facing solar panels. The recent research shows putting panels on east-west facing roofs will smooth the supply of power during the day and prevent spikes of power at midday (www.telegraph.co.uk/news/10996273).

Since the solar power generation of panels will be proportional to the panel side perpendicular to the light of the sun, one can know how much solar energy the buildings with panels can create by calculating the area of the perpendicular component of panels by using a projection image such as in *Figure* 2 *(c)*. Although through the NEDO data map the average quantity of solar radiation of a certain spot is estimated by the positional relationship and the distance from meteorological observation sites, one cannot simulate the shadow of neighbouring terrestrial objects such as buildings or trees.

The sunlight and daylight systems of 3ds Max use the light in a system that follows the geographically correct angle and movement of the sun over the earth at a given location (http://www.autodesk.com/support/3ds-max/learn-explore/). When using this system, one chooses location, date, time and compass orientation indicating a user orientation, and shadow studies of proposed and existing structures will be implemented by 3ds Max. In these studies for simulating shadows, 3D models of city blocks are necessary.

Figure 3 shows a digital map of a town block after land readjustment, an automatically generated 3D town block model, 3D building model with double leaned roof and images by orthogonal projection of various degree depression angles. Leaned roof houses can have large roof boards for panels. In a scene, virtual cameras are placed with a certain direction and depression angle at a certain height, and orthogonal projection images can be shot. Panels on roofs are self-illuminated for easy calculation of the area component perpendicular to the sun.

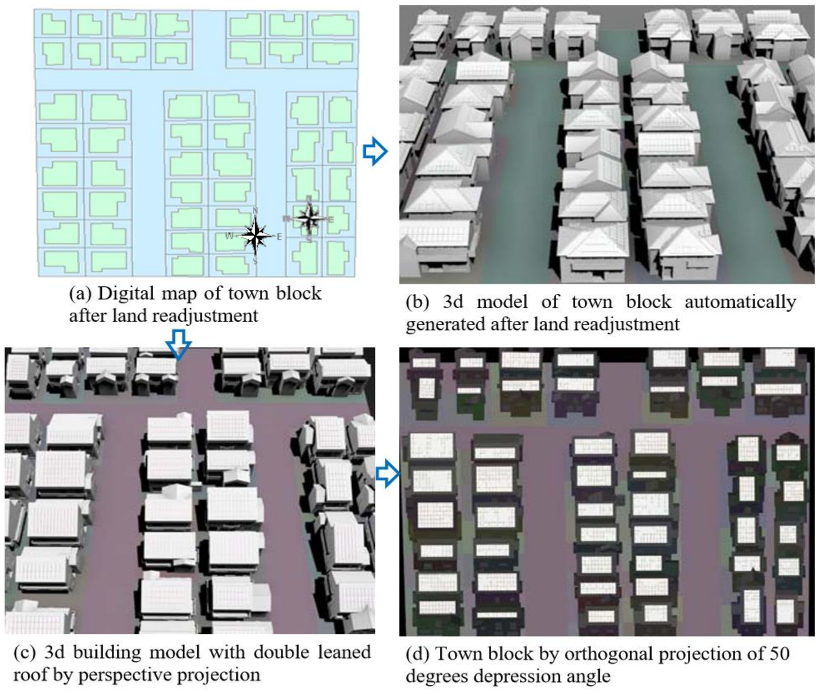


Figure 3. Digital map of town block after land readjustment, 3D town block model, 3D building model with double leaned roof automatically generated, and image by orthogonal projection of various degree depression angles

Since the panels' solar power generation is decided by the panel area of the component perpendicular to the sunshine, we have investigate how the solar power generation varies according to the land rezoning and the shape of the houses by calculating the area of the perpendicular component of panels. *Figure 4* shows ratios of the perpendicular component of the panel area to the total area before and after land rezoning and the changing of the shape of the houses, i.e., double leaned roof structure or not. This numerical experiment for the virtual city block reveals that the shape of the houses, rather than the land readjustment, has a major impact on the solar power generation.

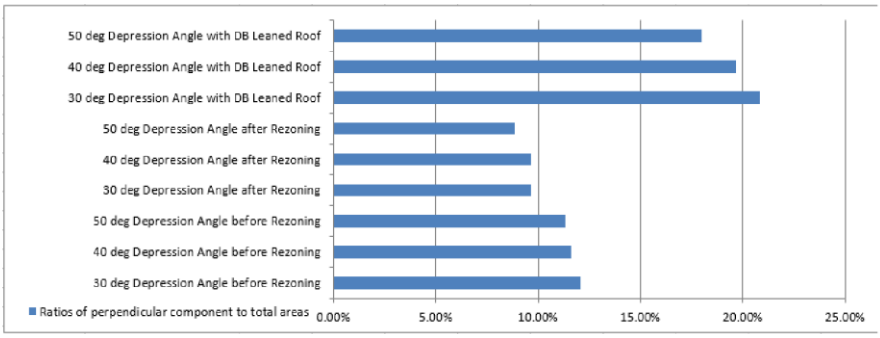
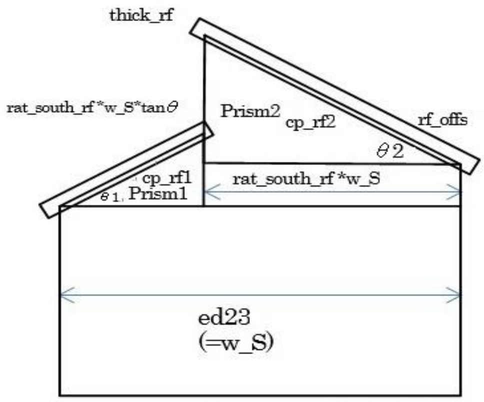


Figure 4. Ratios of perpendicular area component of panels to total area before & after land rezoning, and whether leaned roof structure or not

4.2 Automatic Generation of a 3D Model with Double Leaned Roof

A complicated orthogonal polygon can be partitioned into a set of rectangles. The proposed integrated system partitions orthogonal building polygons into a set of rectangles and places rectangular roofs and box-shaped building bodies on these rectangles, which will be used as a floor plan. A double leaned roof house consists of two leaned roofs. These houses are formed by placing two roof boards, the under roof construction (prism), and a house body, depending on the side view (*Figure 5*) and top view (*Figure 6*).



The width of south facing roof board (wid_rfb) is

$wid\_rfb = side23L + eaves23 + rf\_offs \times \tan\theta$

Here, side23L is $side23L = rat\ \ s\ \ rf \times w\ \ S \times \sqrt{1 + \tan^2\theta}$

'thick_rf' is the thickness of roof boards. 'eaves23' is the length of eave along ed23 direction. θ is the angle of gradient of a roof board.

'rf_offs' is the offset of a roof board from under roof construction.

* The height of south facing roof board (hei_rf) is as follows:

$hei\_rf = st\_heit + rat\_south\_rf \times \tan\theta \times w\_S$

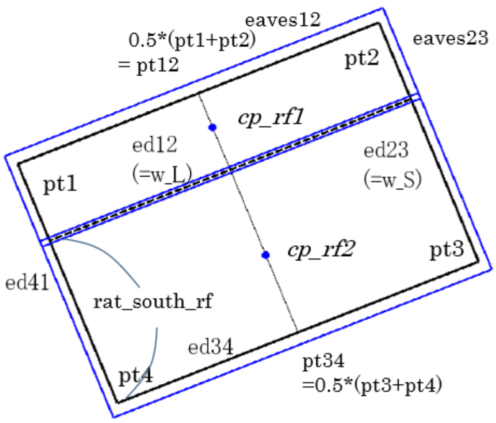
$-0.5 \times wid\_rfb \times \sin\theta - thick\_rf \times \cos\theta + rf\_offs \times \cos\theta$

Here, 'st_heit' is the height of the building body.

Figure 5. Side view for double learned roof, the position of the control point of two roof boards

The placing of these parts of a building is implemented in the following steps. After measuring the length and the direction of the edges of the partitioned rectangle, the edges are categorized into a long edge (w_L) and a short edge (w_S). The vertices of the rectangle are numbered clockwise with the upper left vertex of a long edge being numbered 'pt1' as shown in *Figure 6*. In a Constructive Solid Geometry (CSG) representation, we use volumetric primitives for the creation of 3D models. Each building part or primitive has its own control point ('cp') and local coordinates that control its position and direction. The position of a 'cp' is different in each primitive. As shown in *Figure 6*, for placing building parts properly, their 'cp' is positioned at the point that divides edge12 and edge23 at an appropriate ratio. For example, a prism is used for the construction under roof boards. The 'cp' of a prism lies in one of the vertices of the base triangle in an upright position when a prism is newly created.

The top of a double leaned roof consists of two roof boards (two thin boxes). Since the 'cp' of a box lies in a center of a base, it is placed on the point that divides the line through pt12 and pt34 at the ratio shown in the ground plan (*Figure 6*). The heights of the 'cp' of two roof boards are shown in the side view of a double leaned roof (*Figure 5*).



$$ratio\_s = 0.5\times(1.0-rat\_south\_rf) - \frac{0.5\times(eaves23\times\cos\theta + rf\_offs\times\sin\theta)}{w\_S} + \frac{thick\_rf\times\sin\theta}{w\_S}$$

$$cp\_rf1 = (1.0-ratio\_s)\times pt12 + ratio\_s\times pt34$$

$$cp\_rf2 = ratio\_s\times pt12 + (1.0-ratio\_s)\times pt34$$

* Here, '*rat_south_rf*' is the ratio of width of south facing roof to the width of a rectangle. 'thick_rf' is the thickness of roof boards. 'eaves23' is the length of eave along ed23 direction is the angle of gradient of a roof board. 'rf_offs' is the offset of a roof board from under roof construction.

Figure 6. Floor plan for double learned roof, the position of the control point of two roof boards

To have a larger south facing roof and to get more solar power generation, the ratio of the width of the south facing roof (rat_south_rf) will be increased. The slope of two leaned roofs are given independently so that the system freely creates this type of roof, since the slope of the roof is also an important factor for solar power generation. The width and slope of two leaned roofs will decide the height of the top line of these roofs. If the difference in height between these top lines is greater than a certain length, then the prism (under roof construction) will be in the Boolean operation to have holes for windows, and windows will be installed between two leaned roofs as shown in *Figure 7*, which is the city block full of double leaned roof houses automatically generated after land readjustment.

Figure 7. 3D building models with double leaned roof automatically generated after land readjustment

4.3 Automatic Generation of a Hip Roofed House with Panels

A hip roof is a type of roof where all sides slope downwards to the walls, usually with a fairly gentle slope (en.wikipedia.org/wiki/hip_roof). Thus it is a house with no gables or other vertical sides to the roof. A square hip roof is shaped like a pyramid. Hip roofs on houses could have two triangular sides and two trapezoidal ones. A hip roof on a rectangular plan has four faces. They are almost always at the same pitch or slope, which makes them symmetrical about the centerlines.

In our system, parameters for hip roof formation are the angle of the roof slope (α) and the ratio of the top ridgeline to the long edge of the rectangle floor plan (r_hip_top) as shown in *Figure 8*.

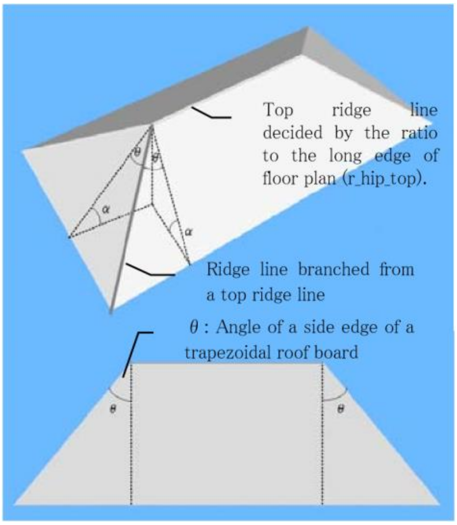


Figure 8. The slope of the roof (α) and angle (θ) of a side edge of a trapezoidal roof board

Since, in most cases, the number of tiles from a branch ridge down to two boundaries (*ed14* and *ed23*) is the same, a branch ridge line will be a bisector of each corner of a rectangle in a top view. Then, the following relational expression is established.

$$\tan\theta = \frac{0.5*\left(1-r_{hip_{top}}\right)*w\_L}{side23L} = \frac{0.5*w\_S}{side23L} = \frac{0.5*w\_S}{0.5*w\_S/\cos\alpha} = \cos\alpha$$

Here, w_L is a long edge and w_S is a short edge of a rectangle of a ground floor. *side23L* is the height of the trapezoidal roof board:

$$side23L = 0.5 \times w\_S \times \sqrt{1+\tan^2\alpha}$$

Usually,

$$r\_hip\_top = \frac{w\_L \;\; - w\_S}{w\_L}$$

Then,

$$\tan\theta = \cos\alpha$$

Figure 9 shows the trapezoidal roof board of a hip roof is overlaid by an array of solar panels. Panels are placed, depending on the angle of a bottom corner of a trapezoid.

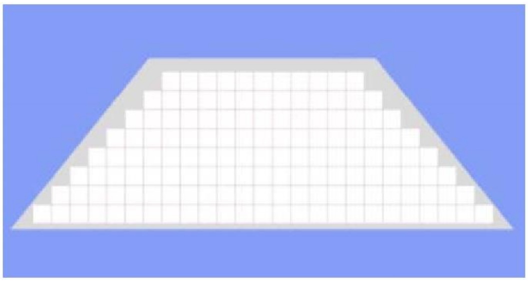


Figure 9. Trapezoidal roof board overlaid by solar panels

5. CONCLUSIONS

To facilitate public involvement for sustainable development, 3D models simulating real or near future cities using 3D CG can be of great use. 3D city models are important in environmentally friendly urban planning that will use solar photovoltaic (PV) generation. However, enormous time and labour has to be consumed to create these 3D models, using 3D modelling software such as 3ds Max or SketchUp. For example, when manually modelling a house with roofs by Constructive Solid Geometry, one must use the following laborious steps: (1) Generation of primitives of appropriate size, such as box, prism or polyhedron that will form parts of a house, (2) Boolean operations are applied to these primitives to form the shapes of parts of a house, such as making holes in a building body for doors and windows, (3) Rotation of parts of a house, (4) Positioning of parts of a house, and (5) Texture mapping onto these parts.

In order to automate these laborious steps, we proposed a GIS and CG integrated system that automatically generates 3D building models, based on building polygons or building footprints on digital maps, which show most buildings' polygon edges meet at right angles (orthogonal polygon). A complicated orthogonal polygon can be partitioned into a set of rectangles. The proposed integrated system partitions orthogonal building polygons into a set of rectangles and places rectangular roofs and box-shaped building bodies onto these rectangles.

In this paper, for placing solar panels on the hipped roof, the structure of an ordinary hipped roof that is made up of two triangular roof boards and two trapezoidal ones has been clarified. To implement efficient PV generation, this paper has proposed to automatically generate 3D building models topped with double shed roofs overlaid by PV arrays. The sizes and positions, slopes of roof boards and main under roof constructions are made clear by designing the top view and side view of a double shed roofed house. For the applied example of the developed system, the solar photovoltaic generation change of a city block has been simulated by performing land readjustment and changing the shape of buildings, ordinary roofed houses or double shed roofed houses suitable for efficient PV generation. This simulation reveals that double shed roofed houses have greatly improved solar photovoltaic generation.

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International review for spatial planning and sustainable development, Vol.5 No.1 (2017), 15-28
ISSN: 2187-3666 (online)
DOI: http://dx.doi.org/10.14246/irspsd.5.1_15

Construction of Urban Design Support System using Cloud Computing Type Virtual Reality and Case Study

Zhenhan Lei[1*], Shunta Shimizu[1], Natuska Ota[1], Yuji Ito[1] and Yuesong Zhang[2]
1 FORUM8 Co., Ltd.
2 Graduate School of Education, Yokohama National University
** Corresponding Author, Email: lei@forum8.co.jp*

Received: Jan 25, 2016; Accepted: Sept 08, 2016

Key words: Urban Planning, Urban Design Support System (UDSS), Virtual Reality (VR), Cloud-Computing type VR (Cloud-based VR)

Abstract: This paper contributes a design support system based on cloud-computing type virtual reality (cloud-based VR) for urban planning and urban design. A platform for Cloud-based VR technology, i.e. a VR-Cloud server, is used to open a VR dataset to public collaboration over the Internet. The digital attributes representing the design scheme of design concepts includes the land use zone, building regulations, urban design style, and other design details of architectural design, landscape, and traffic/architectural environment/sunshine/wheather/noise/inundation/tsunami/earthquake/evacuation simulation. Then practice using this cloud-based VR urban design support system is categorized into three applicable case 'types', synchronized, distributed synchronized and distributed non-synchronized. The effect of the use of this system in urban design and in urban planning processes is evaluated.

1. INTRODUCTION

This paper contributes an urban design support system (UDSS) of cloud-computing type virtual reality (Cloud-based VR) for urban planning and urban design.

The process of urban planning and city design industries in Japan often can be divided into a series of different phases: conceptualization, detail formation, and support and maintenance plan formulization. During conceptualization there are multiple components that must be considered: it is important to examine the neighboring environment, positioning and scale, structural design and durability, and long-term (20-30 years) goals of the project in question. As a project moves on to its detailed formation phase, designers start focusing on the numerous value-added features that are to be integrated into the project. Given that the goal or contracting partner between different phases of the project can vary, the necessity of effective consensus building before transitioning to the next stage is apparent in order to successfully carry out a project.

The aforementioned issue is especially true if the project in question follows the idea of participatory planning, where the locals' or the stakeholders' opinions need to be considered. To achieve this, numerous UDSS have long been developed. However, to ensure such UDSS continues to properly serve its purpose in-between different phases, it is important to seek ways to extend either the reasons or chances that a system can be continually used.

Shiffer (1995) proposes and categories the situation when UDSS is used into the following four categories: 1. the same-place same-timed "synchronized communication within the same room", 2. the same-place differently-timed "non-synchronized communication within the same room", 3. the different-place same-timed "distributed and synchronized communication", and 4. the different-place different-timed "distributed and non-synchronized communication".

Virtual Reality (VR) spaces that can be navigated, as was observed in some large scale VR software such as Second Life or Active Worlds, have the potential to be used for the purpose of consensus building. The incorporation of VR into UDSS, and features such as building reconstruction or renovation design games, urban landscape design, Geographic Information Systems (GIS) or evacuation simulations, has long been a hotly researched or developed topic due to the versatility of VR environments. Brail and Klosterman (2001) proposed a UDSS by incorporating three-dimensional computer-aided design (3D CAD) technologies to achieve effective communication between stakeholders and designers in his research. Nagano and Takafumi (2008) once recreated a virtual environment on the internet for the purpose of surveying local residents for opinions, while publicizing all decisions and procedures of the design committee. Lorentzen, Kobayashi, and Ito (2009) attempted goods transportation inside a VR simulation. Abdelhameed (2012) proposed a VR microsimulation player to visualize the entire construction process of a building. Kawano, Morimoto, and Koike (2005) conducted surveys and examined the usefulness of 3D VR being used as a consensus building tool. Zhang et al. (2015) contributed an application mapping historic buildings based on 3D laser scanning technology. Sugihara (2015) contributed a GIS and CG integrated system that automatically generates 3D building models for UDSS. Shen and Kawakami (2007) have created a web-based application where users can easily create their own VR designs. Shen and Kawakami (2010) proposed an online urban aesthetic design and visualization application. Shen et al. (2013) proposed a UDSS based on 3DVIA and Google Earth to support urban design. Finally, with the advent of cloud computing technologies, UDSS has now been attempting to leverage on this technology.

The fundamental concepts of cloud computing can be traced back to the mainframe computing era as early as the 1950s. Farber (2008) proposed the main advantage of cloud computing as being the elimination of the hurdle of hardware spec limitations; in theory, any user with any device would be able to access and utilize a certain application or data through the internet. Due to this, the proliferation of broadband internet and cloud computing has been a popular subject since 2007 (Grozev & Buyya, 2014).

Existing cloud computing technology research has seen increasingly wider uses. Computer scientists of all sorts have been heavily focusing on cloud computing technologies in the hopes of achieving sustainable information services (Chowdhury, 2012). Further, with the proliferation of smartphone devices, many mobile cloud services have been designed with these users in mind (de Vries et al., 2014; Grover, 2013; Ma, Cui, &

Stojmenovic, 2012; Michael & Clarke, 2013; Ngai & Gunningberg, 2014). Due to cloud computing's expandability, accessibility and potential for cost-cutting, it is extremely popular also in geographical research (Guan et al., 2013; Huang et al., 2013; Marques et al., 2013). On the other hand, cloud computing easily allows big data collection while providing a service or a part of the social infrastructure (Laurila et al., 2013; Whaiduzzaman et al., 2014).

As witnessed, cloud computing allows communication between different devices with more ease and can be argued as having an unrivalled amount of potential uses, hence the popularity across various parties.

Cloud-based VR, with the development of numerous simulation features, and a more customized user interface, can also have many different uses. Especially given the current mass market penetration of mobile devices, an era when devices are no longer bound by space, time, or performance issues, the amount of potential and efficiency of portable computing devices being used for consensus building is unimaginable. With this in mind, Fukuda et al. (2011) examined the usability of a cloud-based VR being used as an urban planning support tool under a distributed and synchronized communication situation for project discussion. Recognizing the potential of using cloud for the purpose of an online collaborative project service, Shen et al. (2014) compared existing technologies or products, such as Google Earth, 3DVIA and cloud-based VR, over technological feasibility.

Having introduced the existing research, it can be argued that cloud-based VR has the potential to bring several major changes to urban planning processes.

This paper is categorized as the following: Section 2 briefly touches on a possible method used to help accelerate cloud-based VR being used for online consensus building. Section 3 describes the fundamental components of cloud-based VR. Section 4 gives three recent case studies of how cloud-based VR has affected the urban planning and design process of respective projects. In Section 5 this paper attempts to argue what exactly has been altered during each planning phase, based on the qualitative findings taken from the three cases. And finally, we will address some of the issues that will and should be addressed in the future.

2. RESEARCH APPROACH

The research method is described here. We developed an urban planning application based on cloud-based VR technologies in 2010, with the purpose of information sharing between different phases of urban planning, and have collected several cases of use during the years since. Due to this paper's limitations, not all the details and design content will be disclosed in this paper, but only some cases of the positive observations.

As was mentioned, we will raise three different cases that involve using a cloud-based VR urban planning support application and examine each of them carefully. The three cases are all different in category: "synchronized communication within the same room", "distributed and synchronized communication", and "distributed and non-synchronized communication"

Lastly, we will examine how using a cloud-based VR urban planning support application can have either positive or negative impacts on the process of urban planning and design.

3. THE FUNDAMENTALS OF A CLOUD-BASED VR UDSS

To aid effectively in urban planning, a UDSS should satisfy the following three fundamental characteristics: visualization of the project, information sharing between different parties, and has the means to conduct surveys to collect as many opinions as possible.

To visualize a project, we have used the 3D VR simulation software UC-win/Road®, in conjunction with VR-Cloud® that is capable of representing a UC-win/Road project through cloud computing, to achieve consensus building. Both are developed and are intellectual properties of Forum 8 Co., Ltd.

By replicating the project as a 3D VR environment through UC-win/Road, abstract information such as the design concept, future outlook, or impact to the neighborhood area that cannot be verbally communicated convincingly, can be represented in a much more interactive and vivid fashion. Furthermore, the software provides numerous simulation features to reproduce elements such as traffic, sunlight, wind, noise, tsunami, flooding, earthquake, or emergency evacuation, as well as the easy incorporation and visualization of numerous Building Information Modeling (BIM) and Civil Information Modeling (CIM) analysis results. Interactive multimedia features such as pop-up text, pictures or sounds can also be used.

Information sharing and opinion collection is done through the VR-Cloud®, which allows for quick and easy accessibility of information. Such as in *Figure 1*, stakeholders or other users will install a client version of VR-Cloud® and access the 3D VR data stored in the server via the internet. The VR data is then rendered by the server and streamed back to the user's computing device; any input commands or manipulation to the VR data is then sent back to the server and immediately reflected and sent back to the user in a real-time fashion. The compression standard of the streamed VR data is done in H.263. By using this method, even thin clients that do not possess a powerful computer can view, control or edit traditionally hardware-demanding 3D VR data without needing to replace their devices, as long as there is a sufficiently stable internet environment. Through this type of cloud computing technology, real-time information sharing of BIM/CIM data has been made possible.

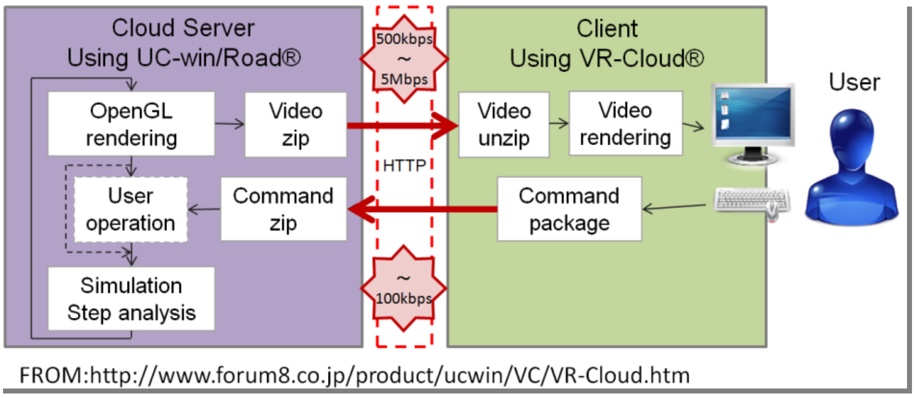

Figure 1. Composition of a cloud-based VR service

To further communicate between various parties, additional features such as 3D bulletin boards or annotation are also available in VR-Cloud® and can be saved and archived into the cloud server to allow distributed or unsynchronized discussion. Using these features, it can be safely argued that such technologies will greatly aid in the urban planning development processes.

4. CASE STUDIES OF USING A CLOUD-BASED VR UDSS

In this section, we will examine three different cases that have made use of the type of cloud-based VR UDSS that was previously mentioned.

4.1 3D Digital City under a Distributed non-synchronized communication situation

By projecting and replicating an existing city inside a virtual setting, we seek to simulate or replicate situations such as either future prospects, potential travel spots, or road work simulations. Combined with a cloud-based VR UDSS, we attempted to achieve effective sharing of information such as simulation/analysis results, aesthetical impact, even under a distributed non-synchronized communication situation, and observed the effects of how it has aided in the collection of opinions or in the decision making process. The case dates as far back as 2011, and a portion of it is represented in *Table 1*, later in this section.

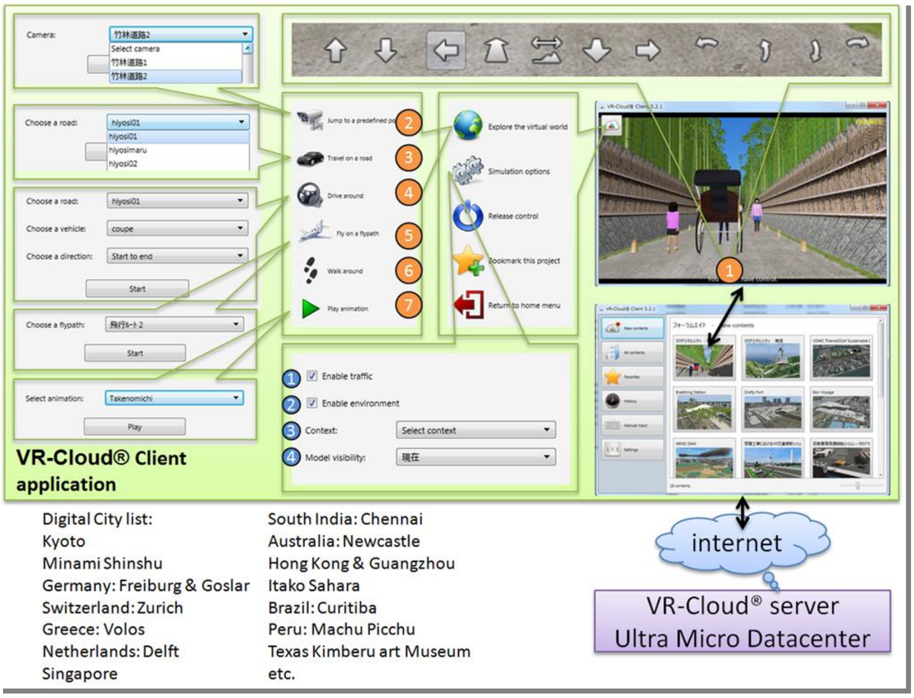

Figure 2. Composition of 3D Digital City System

The following is a description of the system's composition and control interface.

First, clients will download and install the client version of VR-Cloud®. If the client uses a PC, this is done via links that can be accessed through a web browser; if the client uses a mobile device it can be done with either a web browser or a QR-code reader. Once completed, upon accessing the link that is relevant to the project, VR-Cloud® will automatically activate and the 3D VR environments will be displayed. Or alternatively, upon execution of the newly installed software directly, clients will be able to connect to the contents server and can look for the project of interest. Once the VR data is properly accessed and loaded, VR-Cloud® can then be used as a distributed and non-synchronized communication system.

Initially, users are not granted controls to the VR data. By clicking on the icon on the top-left corner, users can take control of the VR environment and freely adjust the camera to their point of interest or navigate through the VR space. Additional advanced control features are introduced in the following section and shown in *Figure 2*:

1) By using these arrow icons, users can interactively manipulate the camera or navigate inside. Depending on the system used, it is also possible to use keyboard and mouse directly.

2) Jump to a predefined position. This command jumps to a certain camera position that was designed by the creator for a specific reason.

3) Travel on road. This command makes travel on the road with limited control possible.

4) Drive around. This command puts users into a car which can be driven.

5) Fly on a fly path. This puts the user into flying mode that follows a predefined path.

6) Walk around. This command allows free movement inside the space with collision elements.

7) Play animation. This command allows users to see an automatic scripted event or presentation that is predetermined by the original author of the VR project. Elements such as multimedia, simulation, or text boxes/captions can be shown.

The following lists some of the elements that can be switched on or off:

1) Enable Traffic. This command enables random traffic on the road.

2) Enable environment. This command enables environmental changes such as time progression, weather effects, or wind (as well as what is affected by the wind).

3) Context. This command allows users to switch between different context and settings (such as traffic volume, environmental themes) that are predetermined by the author.

4) Model visibility. This command enables the visibility of the models, such as trees or buildings that have been placed.

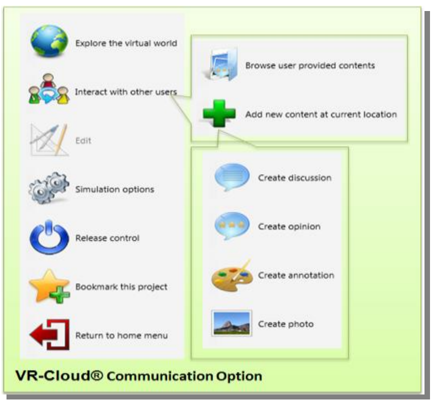

Figure 3. Communication features

To collect the voices of stakeholders, numerous communication options are also available. Such as in *Figure 3*, in VR-Cloud®, it is possible to start a new discussion or view discussions started by others, as well as to upload screenshots. All changes can be viewed independent of each other, making it easy to determine who and what has been done to the project.

Using this system, the simulation of existing cities and the joint synergy between BIM/CIM data, together with the cloud, makes it possible to achieve many of the features that define a VR system while maintaining a high degree of navigation, without any limits imposed by hardware specifications. Users can freely examine elements such as traffic, tsunami, and many other situations from anywhere (see *Table 1*).

Table 1. 3D Digital City content samples that are publicly available

Name	Publication Date	Description	Category
Kyoto	2015.01.21	The digital replica of the popular Arashi-yama tourist spot and the Hiyoshi-Dam located upstream. A night promenade along the roads to Nomiya Shrine is possible.	Night-view, Pedestrian Simulation
Iida, Nanshin Area	2014.10.15	The digital replica of a steep slope that is 800-1000m above sea level in Shimoguri-no-Sato, Iida. All four seasons' views of Nanshin is simulated as well. A high-speed drive through experience inside a 500 km/h Shinkansen (bullet train) is possible.	High-speed Vista Simulation
Freiburg and Gosler	2014.07.10	The area of Vauban and Goslar of the 'Green Capital', Freiburg, Germany, is recreated through 3D data. Green housing designs such as roof solar panels and concepts such as collecting and redirecting rainwater directly into the soil are also properly represented.	Vista and Green Design
Kimbell Art Museum	2011.11.01	Kimbell Art Museum from Texas is recreated via VR, from the exterior into the interior.	Building and Internal Design
xpswmm Tunami Analysis	2012.04.12	Tsunami-analysis results are recreated on a VR environment using xpswmm. The model used here is the replica of a 1 km coastline inside Kamaishi-City, complete with residential buildings, road signs and roads.	Vista and Tsunami Analysis

All VR data had scripted events or auto-navigations created by their respective authors to aid in the understanding of the project and reduce the learning curve of having to navigate through a VR project, supposing the user is unfamiliar with the controls. The scripted events can be paused anywhere at any time and be switched to any other movements the user sees fit. The system's great accessibility ensures all stakeholders, such as local residents, can participate online.

Looking at these distributed and non-synchronized communication use cases, it is observed that a cloud-based VR being used as a visualization and communication tool is more complete than ever. Looking from the perspective of the residents, two major effects can be observed:

1. Ease of building consensus and increase in efficiency

Users can view the project and its various elements visually from anywhere at any time while communicating between different users. The various simulation and analysis results can all be viewed at will and makes the local residents' understanding of the project substantially easier. The drawbacks of an internet-based system, such as latency, low resolution and input lag, are remedied by placing ordinary video files of scripted events.

By having effective communication, as mentioned in the previous circumstance, residents can easily provide more accurate opinions as to what needs to be changed. However, one drawback here is that while opinions are shown as individual icons, there is currently no possible way to export them into the form of a graph or text.

2. Cost-cutting

Automatic presentation via scripted events lightens the burden on the system administrator to run, explain or maintain the data. All cases mentioned here were available 24 hours a day, with a maintenance staff doing simple checks twice a day.

Figure 4. 3D digital city data available on the official HP

4.2 Junior Urban Design Seminar under a Distributed Synchronized Communication Situation

As witnessed, using VR data to ensure effective information sharing to reach consensus has increasingly become more important.

The same UDSS used in this paper is also used in the seminar "Junior Software Seminar: Let's design a 3D VR model!", which has been hosted since 2014. In this seminar, students from elementary to junior high school spend 1.5 days on a workshop and learn to use VR software as a form of extracurricular activity.

As seen in *Figure 5*, the seminar connects six different places into one via teleconferencing to transfer voice and visual data. A lecturer from Tokyo directs and teaches the students on how to create a VR urban space remotely.

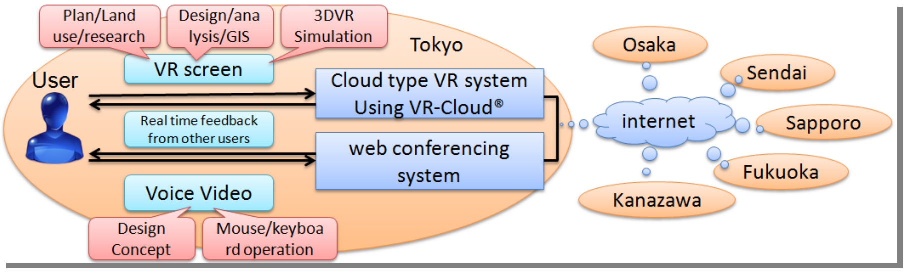

Figure 5. Composition of distributed and synchronized presentation system

During the first day of the seminar, the lecturer shows to the students some basic controls and procedures on PC, which is also transferred to remote areas. Students will experience the making of roads, intersections, bridges, tunnels, trees and the positioning of building models. On the second day, students are given free control over a theme of their choice, and are free to make even exotic projects such as floating cities, or fictional race circuits. Students then do a brief presentation of their project later in the day via the cloud server.

The presentation, as represented similarly to *Figure 6*, is done by having both the presenter and the audience accessing the same VR data via the cloud server. Through this, all participants look at and listen to the presenter's manipulation of the VR data; as usual, participants that are remote to the presenter can still be connected via teleconferencing methods.

As shown in *Figure 7*, all VR city data remain publicized on the server as a user content case and can be accessed by clients after the seminar as well. Notice that, however, in consideration of internet latency, instead of creating a cloud server from the PC used, it is copied to a dedicated VR data server known as the Ultra Micro Data Centre.

With a cloud-based VR, students are able to view and confirm each other's work and borrow or share ideas with each other to further refine their own designs. Eventually, this could result in some excellent urban projects that are created by teenagers or those younger.

Left: Students in Tokyo listening to a presentation held in Osaka. Main screen shows the same VR content operated by a presenter in Osaka. Right: A presenter in Osaka presenting a project remotely via tablet using his hands. Camera feed of Tokyo's classroom shown on the monitor next to the main screen via Web conference system.

Figure 6. Scene of presentation

This case of undistributed and synchronized communication also demonstrates how a cloud-based VR UDSS can be used as a means to effectively connect the various stakeholders or designers to achieve consensus during the design phase of a project, regardless of where. In addition, since an opinion can be reflected immediately in a synchronized situation, this automatically may translate into higher efficiency in communication.

The use of uploading information to a cloud server instead of using the PC itself as a cloud server also greatly reduces internet latency or hardware related video problems. However, internet speed and stability, as well as further improvements to hardware power over time, may eventually eliminate the need to use a dedicated server.

Figure 7. List of contents available and the main menu

4.3 Student BIM/VR Design Contest Judging system

In an urban planning and design project, it is arguably important to invite numerous experts or scholars to join the review and discussions. Upon realizing the original intents or design concepts, they would be able to objectively voice their expert opinions as well. Thus, the easier this process is the better.

Such as in *Figure 8*, a similar system has been used during the fourth "Student BIM & VR Design Contest on Cloud", in 2014. Four regular judges as well as specially invited guest judges were to review, evaluate, and judge all projects submitted.

Figure 8. Composition of the judging system

In this design contest, students all over the world make use of BIM/CIM and VR and compete to design advanced buildings, bridges, cities or landscape data that are relevant to a pre-determined location and theme. The judges will then perform numerous simulations that are relevant to the theme of the competition and determine a winner. The final work is composed in three parts: VR data that set the script for an automatic presentation which can explain the design concept, design data that is created using design software produced by FORUM8 Co., Ltd., and the concept poster.

The following is a description of the system. As seen in *Figure 8*, around 30 projects are made into concept posters as well as being uploaded into a VR exhibition space in the form of a poster object, accessible via a cloud server. As the user navigates closer to the virtual poster object in this VR exhibition space, all expert comments will be shown; clicking on it would load up the cloud application, in a similar fashion to that described in Section 4.1.

In this contest two judgement rounds are presented, one being a distributed unsynchronized communication type for all nominated projects, while a final judgement round would take place in the state of a synchronized communication within the same room.

The nomination judgment phase lasts for one week, where the four regular judges access the uploaded VR data via VR-Cloud® installed devices using unique IDs during their free time. They would then give points to each project panel as well as their expert comments. Students on the other hand, are given a unique ID and can also access the virtual exhibition room to evaluate and provide feedback to their competing teams. Once the nomination round has closed, the top 15 teams with the most points would advance to the synchronized communication within the same room-type final judgement round.

During the final judgment round, as seen in *Figure 9*, all entrants would undergo a defence presentation against the judges' questions or criticisms. All judges would share their discussion via cloud systems.

Figure 9. Final judging round and Grand Prix work published in HP after the final judging

In this case, we have witnessed both a distributed and non-synchronized communication type nomination judgement round, as well as the synchronized communication within the same room-type final round. Participants made effective use of urban planning tools, and were evaluated against different alternative submissions to select the best project possible.

Given that the same systems have been successfully used for different categories of plan communication types, it is safe to claim that a similar system can also be used for similar situations such as during information publicizing, participatory development or public hearings.

However, to maintain fair judgement and information transparency, anonymous reviews and feedback must be considered carefully before implementation.

5. IMPACT TO THE URBAN PLANNING PROCESS DUE TO A CLOUD-BASED VR

Having examined all three cases, it is expected that a cloud-based VR UDSS can lead toward several improvements of urban planning processes.

The visualization features can greatly involve more participants than ever; spatial, conceptual, structural or environmental information can be more smoothly communicated to various parties to ensure that the most reasonable opinions can or are properly reflected.

Once again, since data is accessed via a cloud computing server that can be used regardless of a user's hardware specifications, time or location, all participants can freely participate and share information more easily and effectively, resulting in more opinions to refine the original design. This can lead to two important implications:

The first is that consensus building during the earlier concept or design phase of a project has indeed become easier with a cloud-based VR UDSS. With a tool that effectively involves and connects more people into the project, all parties, regardless of expertise or background, can effectively communicate with each other and eliminate asymmetrical information to obtain a higher level of project understanding. Further, the involvement of local residents greatly improves the transparency and fairness, and is also worth considering.

A second conclusion is that such a UDSS greatly improves the speed, cost performance and efficiency of the urban planning industry. With information parity achieved across different parties, as well as an integrated assistance and simulation package that can be used during all phases of an urban planning process, experts of different backgrounds can effectively communicate with each other and make the necessary evaluations in a much more time-efficient and cost friendly manner. Furthermore, this also allows quicker implementation or testing of opinions from numerous parties, potentially achieving higher reliability, as well as trust.

6. CONCLUSIONS

In this research, a cutting-edge cloud-based VR urban design support system is introduced. Three different cases of this system have been examined and all three showed implications of how such a system can aid in the increase in quality, aesthetical impact, consensus and trust, reliability, transparency, efficiency and cost-effectiveness of urban planning processes. Based on these findings, we examined how this cloud-based VR urban design support system can have considerable improvements over urban planning processes to help bring a project to a successful proposal. The contributions of this research are described in the following paragraphs.

Because the system places great demands on graphics and network speed of the server in which 3D VR data is stored, if you share your VR world to multiple users simultaneously, the fluency may be reduced, consequently spoiling the effect of consensus building. As an ideal solution, a special server should be used and a network for VR-Cloud designed to achieve seamless and fluent real-time rendering.

In the case of synchronized communication, even at times when the operator shares the same camera view of the 3D VR environment at the same angle of view with other users, the focus needs to be highlighted quickly and efficiently to attract attention from users every now and then. As part of our future development, we consider allowing the cursor moved by the operator to be viewed by other users browsing the same 3D VR environment so that the operator could spend less time describing the concept.

Because of the limitation in which only one operator can take control of one VR data set at a time, in the case of non-synchronized communication, several users logging into the same data at the same time may lead to a long queue of users waiting to take control of the VR data. Hence the necessity to support multiple inputs from multiple users.

Future prospects to refine these tool designs include elements such as further design simulation to assist in designs, a more progressive 4D VR environment that considers temporal elements, as well as the support of future wearable computing devices.

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International review for spatial planning and sustainable development, Vol.5 No.1 (2017), 29-44
ISSN: 2187-3666 (online)
DOI: http://dx.doi.org/10.14246/irspsd.5.1_29

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

Yuanyi Zhang[1,2], Zhenjiang Shen[1,2*], Kai Wang[3], Fumihiko Kobayashi[2] and Xinyi Lin[2]
1 School of Architecture, Fuzhou University
2 School of Environmental Design, Kanazawa University
3 One Foundation
** Corresponding Author, Email: shenzhe@staff.kanazawa-u.ac.jp*

Received: Jan 02, 2016; Accepted: Sept 26, 2016

Key words: Reaching Consensus, Online Discussion, Cloud-based Virtual Reality, Disaster Prevention Park, Sustainable Urban Design

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

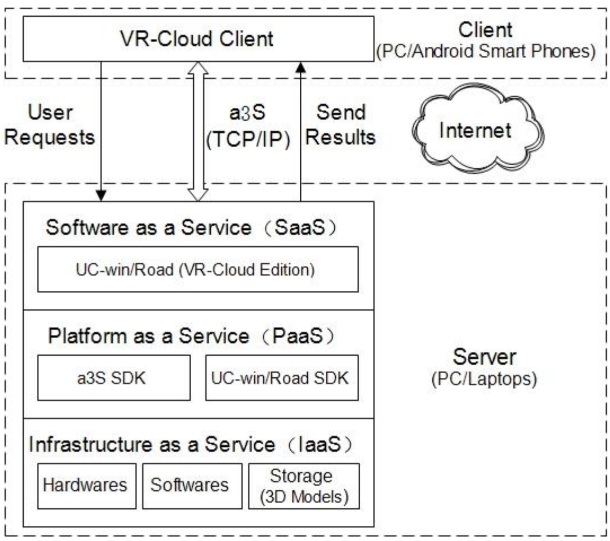


Figure 1. The framework of Cloud-based VR Platform

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.

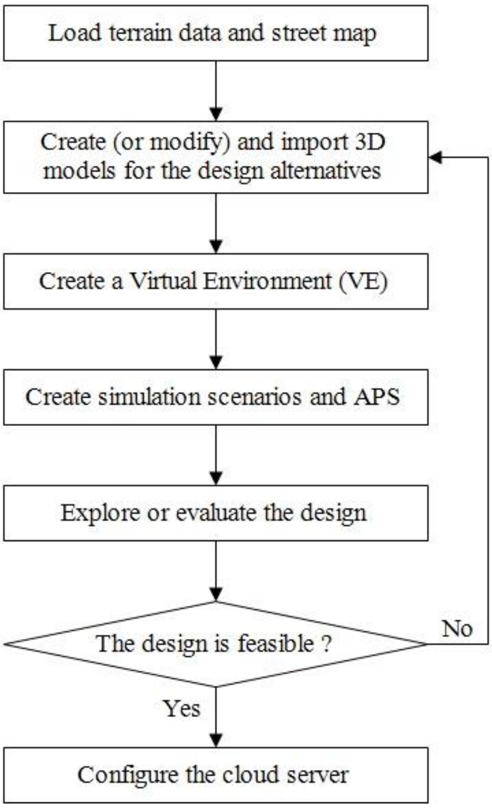


Figure 2. The working process of Cloud Server

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*.

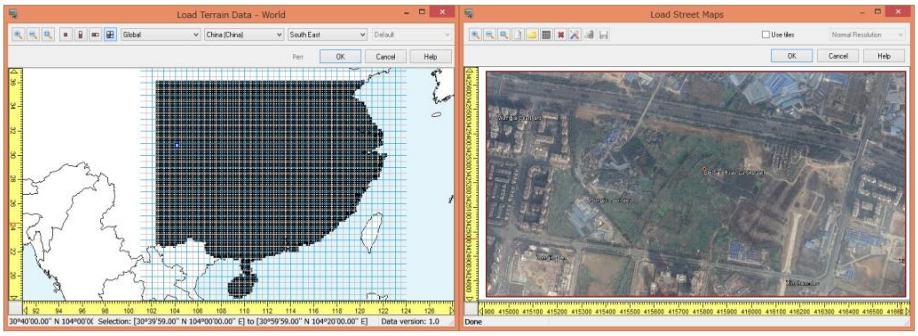


Figure 3. Load terrain data and street map

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

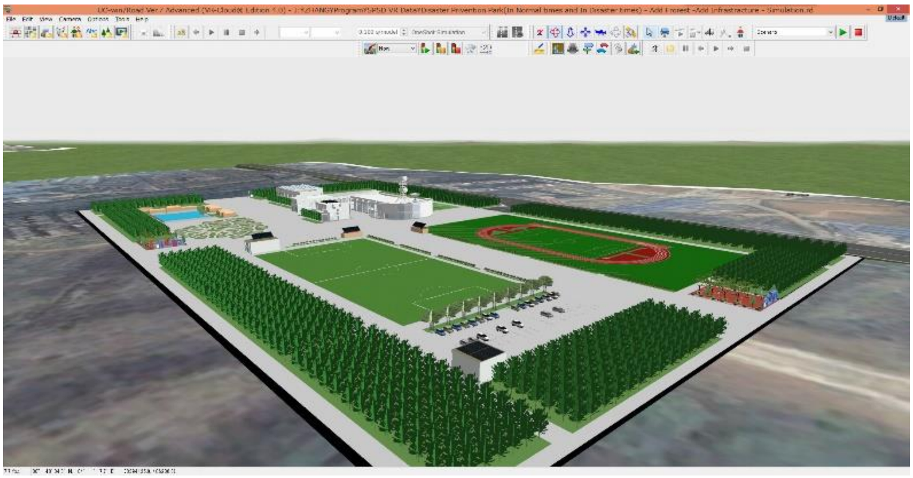


Figure 5. The virtual environment of design alternatives

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.

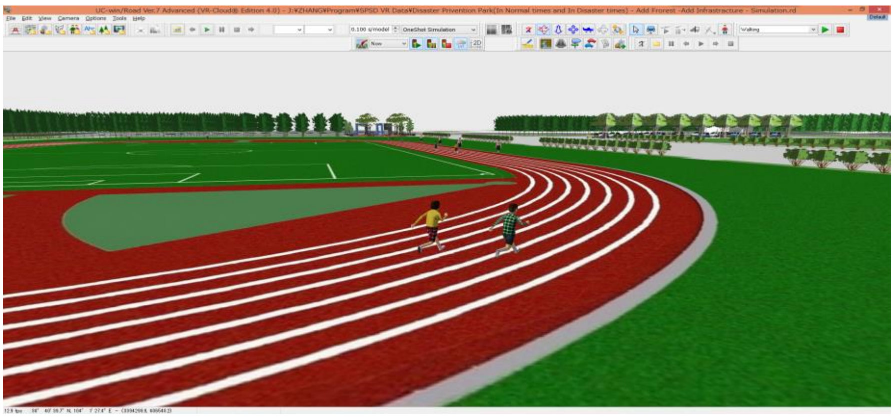


Figure 6. Simulation scenario of playground in normal times

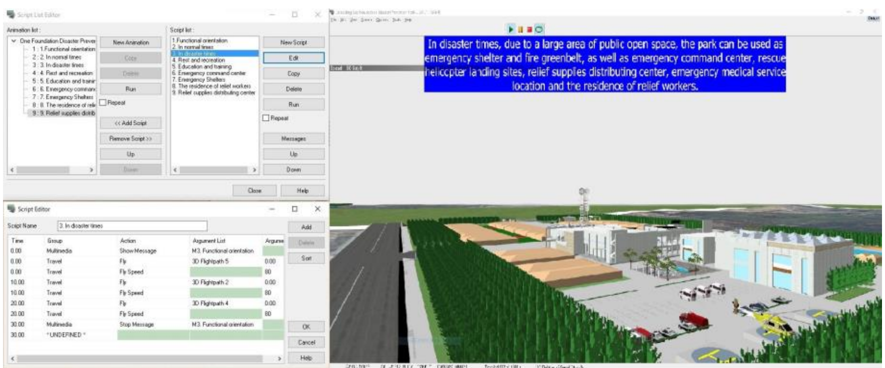


Figure 7. APS of One Foundation's Disaster Prevention Park and its running result

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[illegible]	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.

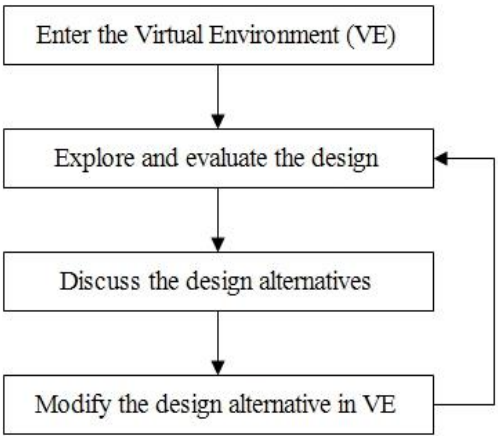


Figure 8. The working process of consensus building in design alternatives report meeting

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*.

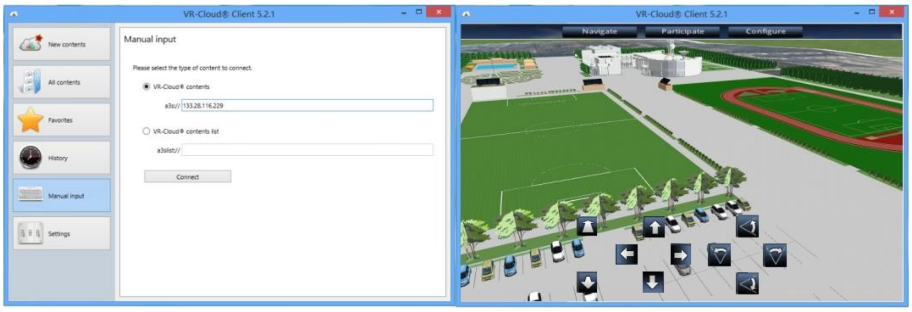


Figure 9. Enter the virtual environment

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.

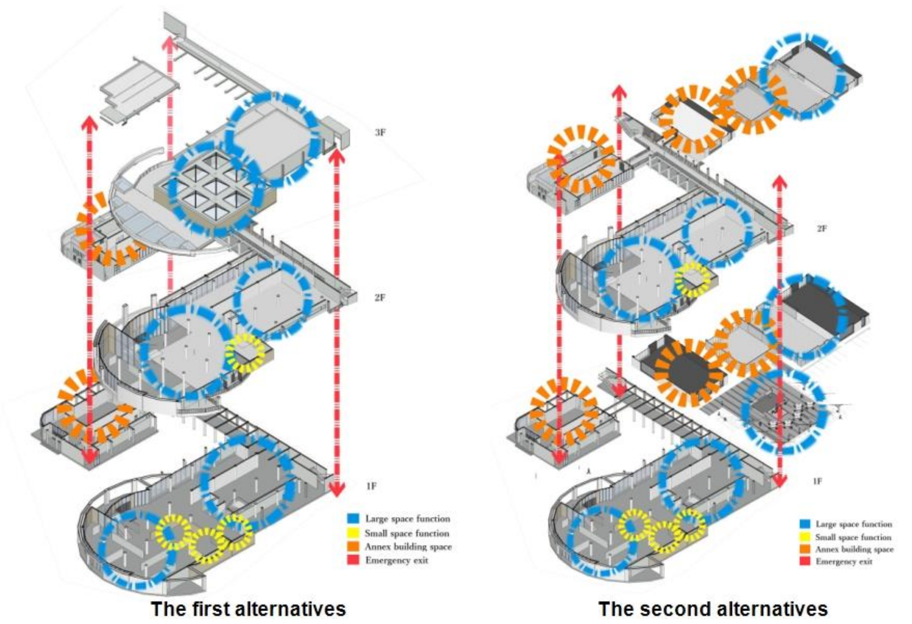


Figure 10. Functional planning of Disaster Management Centre in two alternatives

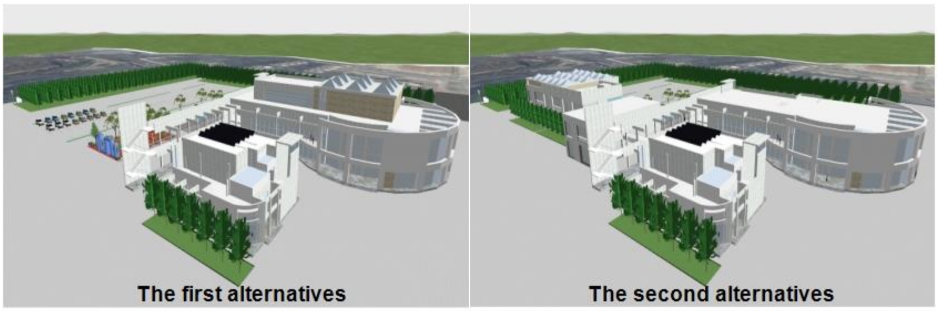
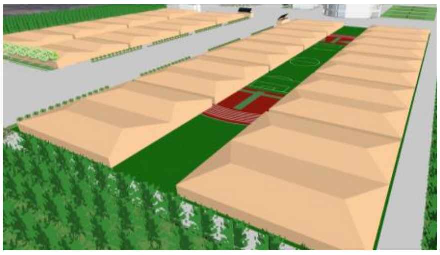
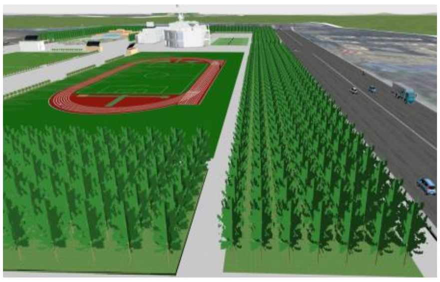
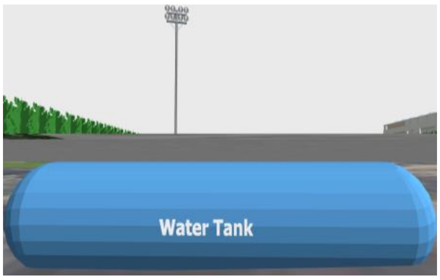
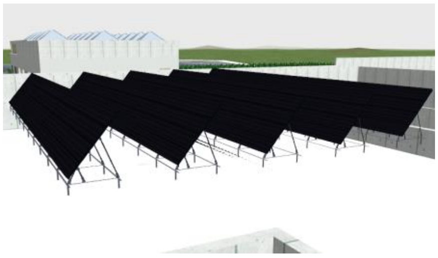
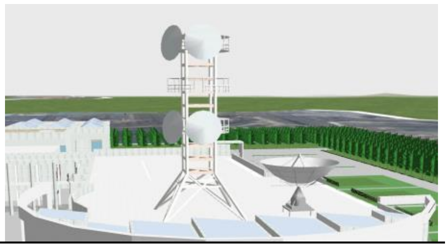


Figure 11. 3D effect drawing of Disaster Management Centre in two alternatives

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 $2m^2$.	
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.

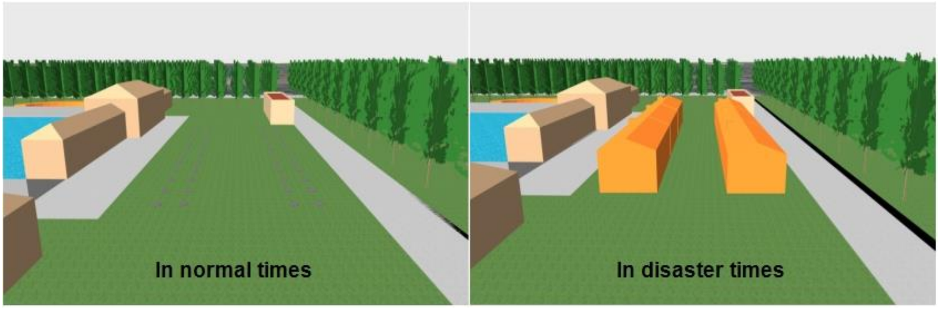


Figure 12. Emergency toilets and bathing facilities

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.

ACKNOWLEDGEMENTS

This work is supported by the Education Scientific Research Project of Young Teachers in Fujian Province (No.JA13048), and the National Scholarship of China (No.201308350110).

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International review for spatial planning and sustainable development, Vol.5 No.1 (2017), 45-54
ISSN: 2187-3666 (online)
DOI: http://dx.doi.org/10.14246/irspsd.5.1_45

Assessment of the Process for Designing an Apartment Building through IM & VR

Jun Imaizumi[1*]
1 UC-1 Development Group 1 Analysis Support Team, FORUM8 Co., Ltd.
** Corresponding Author, Email: imaizumi@forum8.co.jp*

Received: Jan 22, 2016; Accepted: Oct 26, 2016

Key words: Design tool, Simulation, Computational Fluid Dynamics (CFD), Virtual Reality (VR), Cloud Computing type VR, Building Information Modeling (BIM)

Abstract: An increasing amount of attention worldwide has been diverted into using Building Information Modeling (BIM) tools and simulations via BIM models in the field of architecture. BIM modeling and the effective use of various types of numerical and quantitative simulation and analysis are used throughout architectural processes. Stakeholders of various parties can be better informed about projects and may offer their feedback in a more effective and rapid manner to foster better, but also speedy, decision-making, hence this type of technology is so important. In this paper, various types of software and solutions based on Information Modeling (IM) and Virtual Reality (VR) are utilized in the design of a company dormitory. Simulations via a BIM model are performed and a cloud-based 3D Virtual Reality is used for consensus building. This paper examines the detailed process of the project, the effectiveness of feedback on the design, and the process of reaching consensus. In addition to what has already been done or what is currently available, this paper also presents a summary of what will be offered in the future in terms of BIM modeling, environment simulation, and VR simulation, collectively.

1. INTRODUCTION

An increasing amount of attention worldwide has been diverted into using Building Information Modeling (BIM) tools and simulations via BIM modeling in the field of architecture. BIM modeling and the effective use of various types of numerical and quantitative simulation and analysis are used throughout architectural processes. Stakeholders of various parties can be better informed about projects and offer their feedback in a more effective and rapid manner to foster better, but also speedy, decision-making, hence this type of technology is so important.

A company dormitory (FORUM8 Takanawa House) is planned to be constructed at Takanawa-3-Chome, Shinagawa-ku, located near Shinagawa Station which is accessible by train, approximately 10 minutes from Tokyo Station. The site on which the company dormitory building is planned to be constructed has an area of 170.27m^2 and is located within one of the residential zones of Central Tokyo. The apartment building (company dormitory) will have a total floor space of 400m^2 with three floors above ground and one underground floor, and will accommodate nine residents in total. In addition, some public empty spaces are currently planned to be reserved for business meetings/presentations.

In this paper, various types of software and solutions based on Information Modeling (IM) and Virtual Reality (VR) will be utilized during the design process. Simulations via a BIM model will be performed and a cloud-based 3D Virtual Reality is used for consensus building. In the design process, BIM modeling, wind analysis, energy analysis, construction simulation, flood/evacuation simulation, examination of the design using 3D VR, and open discussion via Cloud Computing type VR for consensus building were planned and put into practice. In addition, the implementation of Building Environment and Energy Management System (BEMS), or Smart House, technology is also under consideration.

Recently, many researchers have focused their development or application of IM and VR on urban planning and design. For example, Shen and Kawakami (2010) proposed an online urban aesthetic design and visualization application. Lorentzen, Kobayashi, and Ito (2009) reported case studies incorporating a 3D VR system. Fukuda et al. (2011) examined the usability of a cloud-based VR as an urban planning support tool. Imaizumi, J (2010) and Imaizumi, J. et al. (2011) reported a design process using BIM, VR and other simulations for competition. Shen et al. (2013) proposed an Urban Design Support System based on 3DVIA software and Google Earth to support urban design. Wang, Yan, and Liao (2013) proposed low carbon design and planning concepts in urban planning. Guan et al. (2013) reported usage of point cloud data in a cloud computing environment.

Having introduced the existing research, it can be argued that a 3D VR has the potential to bring several major changes to the architectural design and consensus building process.

Therefore, this paper will examine the detailed processes of a project, the effectiveness of feedback on the architectural design, and the process in reaching consensus. In addition to what has been done or currently available, this research will also suggest a summary of what will be offered in the future in terms of BIM modeling, environment simulation, and VR simulation, collectively. *Figure 1*, below, illustrates the workflow for the apartment building.

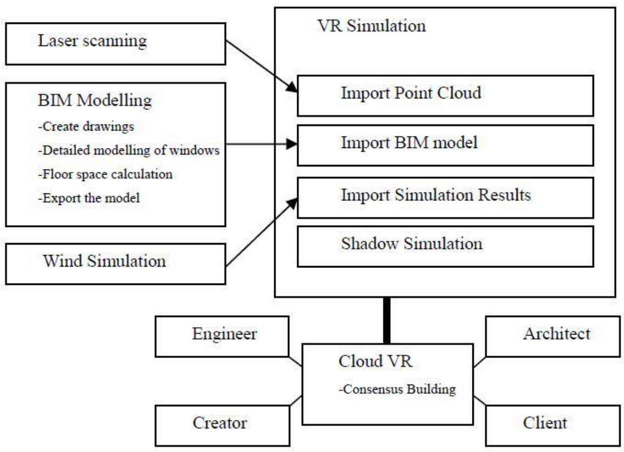


Figure 1. The workflow of Design Process through IM and VR

2. BIM MODELING

As part of BIM, the building was constructed using an integrated BIM solution, Allplan (developed by Nemetschek Allplan Deutschland GmbH), and designed by IKDS (Ikeda Kokubun Design Studio). *Figure 2* shows a rendered image of the building.

Figure 2. Rendered image of the appearance of the building

2.1 Creating floor plan, section and elevation views of the building

Based on the 3D BIM model, the floor plan, section and elevation views were automatically created. 3D modeling can also be performed with the same intuition derived as if drawing a floor plan. Section and elevation views were created using the "Associative view" function. *Figure 3* shows elevation and section views of the building. However, when creating the section map was attempted, two technical difficulties with the software were observed. If the associate view of a file contains another associate view, or if the scales are different, the walls on the further side of the section map, as well as the windows on the wall, are not properly displayed.

Figure 3. Elevation and section views of the building that are automatically generated by Allplan

2.2 Font BIM modeling and calculation

In this research, we used dedicated BIM tools, “Wall” and “Door, Window” in Allplan for the 3D modeling. In the case of windows, we also made use of the more flexible customization function, SmartPart, and provided detailed information to the design studio. In the SmartPart editor window, various elements such as a window’s frame, sash, direction of opening, or material, can be customized, to create a customized design. Furthermore, by editing the scripts in SmartPart, the shape can also be altered at will. Most window design tools do not support the “double sliding window” that is more common-place in Japan. *Figure 4* illustrates the editing window when changing the script in SmartPart, complete with the direction of the opening in accordance to the standards proposed by Japan Institute of Architects, via script editing.

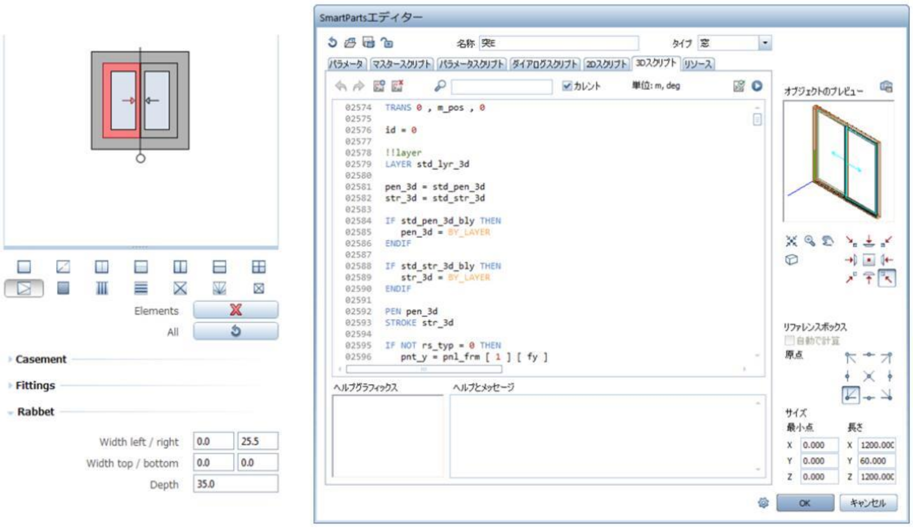
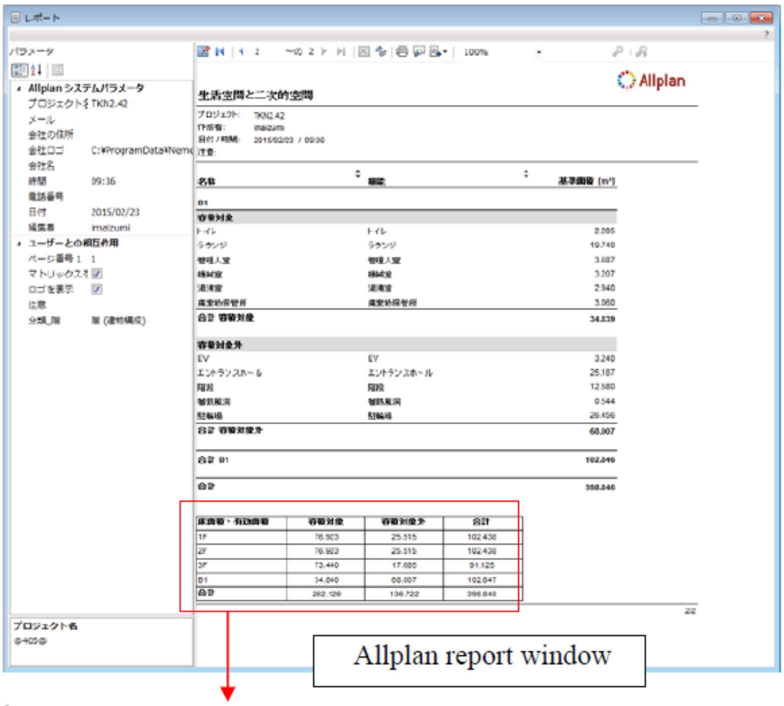


Figure 4. Editing window when changing the script in SmartPart

2.3 Calculation of the legal floor space

Numerical calculations are performed by loading and customizing a client report definition file template (.rdlc) from the Microsoft Visual Studio Report Viewer, directly in Allplan. The numerical calculation is used mainly for counting or computing the number of objects placed, the volume and the surface area of the 3D object. In our project, we attempted to calculate the floor area ratio to be used for calculating the legal floor space later. To do this, we made some rooms and grouped them together into different groups with Allplan’s “Room” function, and calculated the area of every group. We also had edited the report definition file so that the rentable and non-rentable areas are both displayed as shown in *Figure 5*. The “Room” function also allows room to be defined by measuring its outer frame. Using these functions, we have demonstrated that the data required for building certification applications, such as the area of the firewall, net floor area, or rentable area, can be generated and effectively used for rental services.



Floor	Counted	Not Counted	Total
1F	76.923	25.515	102.438
2F	76.923	25.515	102.438
3F	73.440	17.685	91.125
B1	34.840	68.007	102.847
Total	262.126	136.722	398.848

Figure 5. A report customized for floor area calculation

2.4 Data export and coordination

The model data created in Allplan can be imported into the Real-time Interactive 3D VR Simulation and Modeling Software UC-win/Road under the following format (see *Table 1*).

Table 1. Model data coordination between Allplan and UC-win/Road

File Type	Extension	Import Method in UC-win/Road	Description
3DS	.3ds	Import 3ds	Objects' surfaces are imported as separated layers. Cannot be integrated in Allplan.
COLLADA (1.4.0 , 1.5.0)	.dae	Import fbx	Each object is imported as separated layers. If objects are made of the same materials they can be edited together in UC-win/Road, with detailed elements such as reflectance also customizable.

If an object's surface file (*.surf) or related picture files contain Japanese text in the file names, then the .dae object itself or the texture may not be imported properly. Also, if using texture exported from .3ds, then the texture file name needs to be under eight half-width letters or numbers.

However, it should be noted that it is advisable to not have surfaces intersect or placed too close to each other when creating data inside Allplan. In some cases, when such intersections are intended to represent multiple layers in the walls, in a 3D VR setting this may cause the surfaces to either clip through each other or cause fluttering.

3. ENVIRONMENTAL SIMULATION AND VR SIMULATION

3.1 Wind Analysis

Wind analysis was performed through simulation at an urban scale to verify how the prevailing wind changes its course and blows into the site.

The 3D geometry of the surrounding pieces of terrain, roads and buildings built by the 3D VR software were loaded into OpenFOAM, an all-purpose Computational Fluid Dynamics (CFD) tool, in order to perform wind analysis. As the time required to complete the wind analysis depends on the extent of the area to be analyzed and the size of the grids, an analysis was performed on a wide area extending 400m from North to South and 250m from West to East in the first phase, and then a more detailed analysis was performed by limiting the range to the area covering the building site alone in the second phase.

In the first phase, prevailing wind in the month of July (when the outside air can be substituted for an air conditioner to be used as draft or for natural ventilation), based on data from the Japan Meteorological Agency, was analyzed to determine its wind direction and average velocity, which were northward and 3.83 (m/s) as shown in *Table 2*, and the wind analysis was performed based on the table. *Figure 6* shows the frequency of occurrence during sleeping hours (11pm - -6am), in July.

The results of the wind analysis were imported to the 3D VR space built by UC-win/Road for visualization. *Figure 7* shows the image of results imported by 3D VR. There is a park north of the construction site. Since a park forms a depression amidst a group of buildings, the wind will tend to slow down as it reaches the building. This tendency was confirmed in the visualization. The second phase is planned for the near future.

Table 2. Wind speed and temperature in July, at Haneda

	All Day	Morning to Early Night (7am-10pm)	Late Night to Dawn (11pm-6am)
Average wind speed (m/s)	4.56	4.96	3.83
Average temperature（℃）	25.88	26.74	24.67

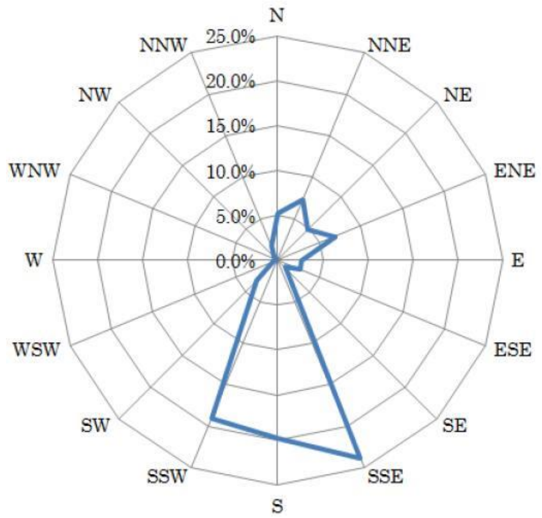


Figure 6. Frequency of occurrence during sleeping hours (11pm-6am), in July

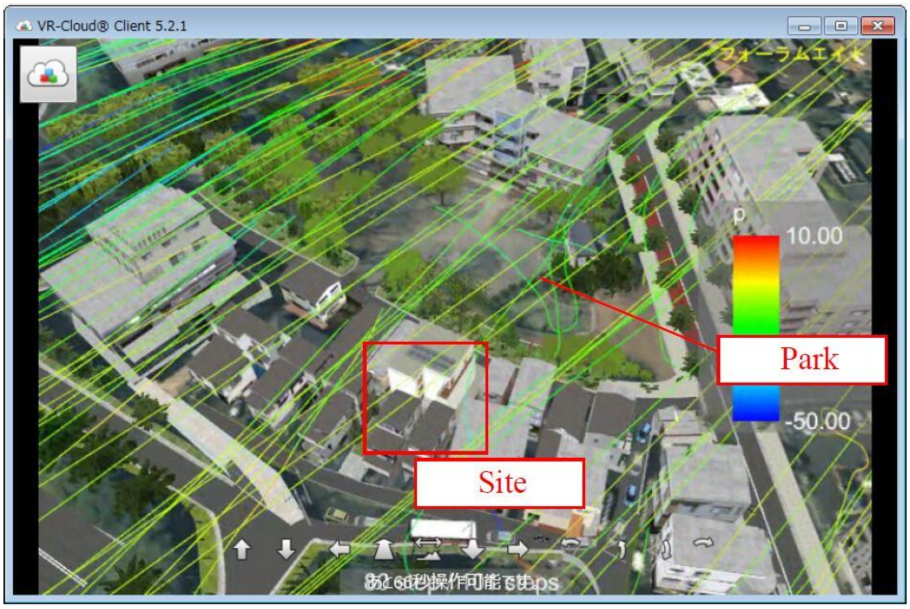


Figure 7. Phase One wind analysis (shown using VR-Cloud)

3.2 Sunshine and Shadow Simulation

Before acquiring the land, a sun shadow simulation was performed to ensure the shadow of a high-rise building under construction adjacent to the dormitory would not have any detrimental effects. While on paper this was done and submitted during the winter solstice, in a VR setting the date and time can be manipulated at will. This grants us the advantage of reviewing sunlight and shadow regardless of the actual date. *Figure 8* illustrates the sun shadow simulation in VR.

Figure 8. Evaluation of sunshine and shadow

3.3 Point-cloud Modeling

3D laser scanning technology has often been used to get the point cloud model of buildings (Zhang et al., 2015). In order to further take into account other various elements inside VR, a 50m terrain mesh data was loaded into UC-win/Road, which was then used to build buildings and roads surrounding the construction site and position the surrounding trees in their correct geographic location based on onsite surveys and observations, all on top of the loaded terrain, to reproduce the surrounding environment realistically. Furthermore, point cloud data consisting of approximately 3 million points collected by 3D laser scanners from the surrounding area were loaded into UC-win/Road to be used as an accurate map on which to place models, or as a guide in understanding the terrain of the site and its surroundings as they are in the real world, as well as the detailed physical relationship between the site and the existing surrounding buildings. As for neighbouring fences, numerical values measured using one of the functions of the 3D laser scanner which can measure the distance between any two given points were used as a guide in BIM modeling. *Figure 9* illustrates the measurement of a point cloud and the 3D model from the measured values.

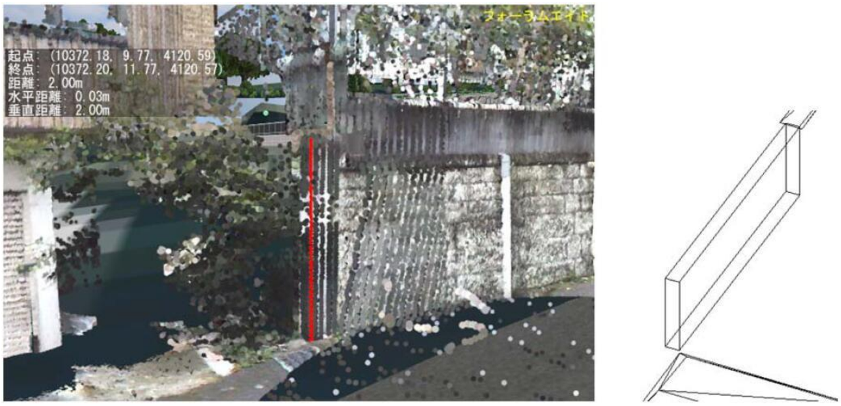


Figure 9. Neighboring fence’s height is reflected in the BIM model

3.4 Coordination via VR-Cloud

Simulation engineer, VR creator, company staff as client, and an architect who designed this building all utilized the VR-Cloud to have a proactive discussion amongst one another.

The building model was then reflected into the 3D VR cloud solution software, VR-Cloud, to achieve a higher degree of communication with the design studio over topics such as surrounding environments and wind analysis. Three different exterior design proposals were discussed and ultimately one was selected, as well as numerous variations to the internal design of the building, while editing and applying any changes or feedback directly into the VR-Cloud server in real-time. It is also possible to invite employees who may be living in the building to offer their opinions. Essentially, this is a case of an unprecedented new process of design project planning, information sharing, and consensus building. *Figure 10* shows different proposals of the external design.

Figure 10. Evaluation of the external design. Three different proposals and the one selected for adoption.

4. CONCLUSIONS

With BIM software, Allplan and its SmartPart script editing, as well as the customization of report templates, we were able to successfully design and recreate a Japanese-styled architecture in this case study. By successfully having imported models into UC-win/Road, we were also able to create some modeling tips that can be applied to future Allplan projects. Furthermore, we have also demonstrated a hub software that is capable of providing numerous different types of simulation software data.

By having BIM aiding in the creation of a more efficient project planning process, the time saved due to this higher efficiency can be reallocated into further refinements to the original design to accomplish a project that is high in added-values. While in this case study we only ended at the design phase, we have demonstrated how it is possible to achieve numerous complicated design considerations via IM and VR solutions. It can be argued that the bigger the scale of the project, the more the benefit that could be gained via such a solution.

The interactive VR software UC-win/Road has performed a pivotal role in the visualization of individual simulation and analysis results. With a 3D recreation of the simulation, it is much easier for us to relate it to reality and to have a better picture of what may truly result. Furthermore, since all simulations are done in real-time without delay, it is much easier to formulate feedback or comments. When further combined with a cloud-based VR, in this research, we have essentially accelerated the process of consensus building between various parties of stakeholders. The cloud-based VR system mentioned here will be further used during construction phase, as well as even after completion, and will have its 3D VR data updated according to each new status or proposal. While a cloud-based VR allows anyone the easy navigation throughout a virtual world, finding an intuitive way to display numerical or written data has been an area worth further investigation. We plan to develop a newer interface and features for displaying such information in future versions of the software.

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International review for spatial planning and sustainable development, Vol.5 No.1 (2017), 55-70
ISSN: 2187-3666 (online)
DOI: http://dx.doi.org/10.14246/irspsd.5.1_55

Green-energy, water-autonomous greenhouse system: an alternative-technology approach towards sustainable smart-green vertical greening in smart cities

Paiyao Hung[1] and Kuanghui Peng[1*]
1 College of Design, National Taipei University of Technology
** Corresponding Author, Email: khpeng@ntut.edu.tw*

Received: Feb 03, 2016; Accepted: Oct 15, 2016

Key words: Green-energy, Water-autonomous Greenhouse System, Sustainable, Smart-green, Vertical Greening, Smart City

Abstract: By means of "going greener", "getting smarter" and "converging smart-green", an innovation-driven smart city could address the steps toward more sustainability and aim toward improved human well-being. A vertical greening means a vertical triumph of greenery in a high density urban area, in some ways it displays the level of smartness and greenness in a city. Researchers have suggested the use of vertical greening in urban areas to improve sustainability of the environment. However, conventional vertical greening is in open fields, unprotected, threatened by climate disasters, lacking in better controlled climate conditions and plant response-based circumstances. In addition are always the challenges of energy saving, reduction of CO^2 emissions, reduction in water use and in pesticide use. A greenhouse system could instead solve different facets of these problems in conventional vertical greening to achieve an optimal balance between an efficient environmental control and efficient plant use of available resources. The greenhouse solution appears to be intellectually justifiable, adaptable and innovative, and appears beneficial to a smart-green and sustainable smart city. Through the literature review and foresighted design point of view, the paper first summarizes the major concepts and trends of smart cities, vertical greening usage and new greenhouse technologies, and approaches an introduction to the relationship and development between vertical greening and greenhouse systems, and is followed by a presentation of a proposed novel prototype of a green-energy, water-autonomous greenhouse system. The sophisticated and multi-disciplinary greenhouse system reveals its innovations and advantages by using water resources and solar energy in a rational way, fit for an alternative-technology approach towards sustainable smart-green vertical greening in smart cities. Aimed at improving responsiveness, efficiency and performance for environmental and resource sustainability, and also aimed at improving well-being, the system is expected to be a foresight with simplicity in evolutionary vertical greening. By means of Industry Foundation Classes file format, with a true BIM model consisting of a digital prototype of the physical elements, further design of the system will allow us to simulate an ideal greenhouse type of vertical greening and understand its behavior in both the computer environment and actual on-site construction, as well as allow the building of a smart-green point cloud with BIM workflow on any network in a smart city.

1. INTRODUCTION

1.1 Background

The 21st century has been described as the “Urban Century”. Cities around the world are faced with complex social and ecological challenges caused by population growth, urbanization and climate change. In envisaging these challenges, cities are increasingly concerned with providing innovation-driven, more environmentally-responsive, resource-efficient materials and technologies, and with providing performative answers to strengthen future viability of cities and to improve the quality of life for citizens in future urban communities. Accordingly, the use of the term “green city” and “smart city” has sharply increased in recent years.

Both ‘green’ and ’smart’ are umbrella terms. According to Attmann (2009), ‘green’ involves a combination of values—environmental, social, political and technological—and thus seeks to reduce the negative environmental impact by increasing efficiency and moderation in the utilization of materials, energy and development space, so green is an abstract concept which requires the inclusion of the following terms: sustainability, ecology and performance. According to Hatzelhoffer et al. (2012), considering the term from an Anglo-American perspective, ‘smart’ can have a whole array of meanings. It can be used in the sense of something being brisk, elegant, competent or fashionable, as well as meaning clever or intelligent. An international scientific team led by Caracliu in 2009 drew up six criteria and formulated the definition of a smart city, “We believe a city to be smart when investments in human and social capital and traditional (transport) and modern communication infrastructure (ICT) fuel sustainable economic growth and a high quality of life, with a wise management of natural resources through participatory governance” (Hatzelhoffer et al., 2012). According to Posada, the term ‘sustainability’ is broader in its reach than ‘green’, addressing the long-term impacts of the built environment on future generations and demanding an examination of the relationship between ecology, economics and social well-being (Kwok & Grondzik, 2011).

To sum up the above, considering the overall umbrella concepts, both ‘green’ and ‘smart’ could be combined into ‘smart-green’ on the basis of sustainable materials and technologies, resources and environment. By means of ‘going greener’, ‘getting smarter’ and ‘converging smart-green’, an innovation-driven smart city could address the steps toward more sustainability and aim at improved human well-being.

Vertical greening, according to Peng, Kuo, and Lin (2015), can increase the amount of urban greening, reduce urban heat island effects, improve the quality of outdoor and indoor air, beautify urban landscape, lower indoor temperatures, increase energy efficiency, protect building structures and reduce noise. Expanding the use of vertical greening is a good way to rehabilitate high-rise, congregated house, building façades and sustain a green wall system for improving the sustainability of the environment (Peng, 2013). Moreover, beyond the environmental function of providing horticultural cultivars to the urban landscape, vertical greening can also be a type of agricultural cropping for food production in a city. A vertical greening means a vertical triumph of greenery in a high density urban area and its surface environment, it suitably displays the level of smartness and greenness of a city.

However, conventional vertical greening used to be in open fields, unprotected, threatened by climate disasters, such as high wind speed and heavy rainfall, lacking in better controlled climate conditions and plant-response-based circumstances, and are now used to face the challenges of energy saving, reduced CO^2 emissions, reduction in water use and in pesticide use. However, water scarcity and the large demand for primary energy are still serious handicaps for the sustainability of the actual production system.

On the one hand, progressive technological solutions, developed from traditional to modern and from conventional to unconventional solutions, will help vertical greening itself to be more smart-green and sustainable. But on the other hand, a greenhouse system could additionally solve different facets of the problems in conventional vertical greening because a greenhouse system which minimizes the use of water and energy could be developed by an increasingly sophisticated and multi-disciplinary approach to achieve an optimal balance between an efficient environmental control and efficient plant use of available resources. This appears to be much more intellectually justifiable, adaptable and innovative, and appears much more beneficial to a smart-green and sustainable smart city.

1.2 Motivation and Objectives

The purposes of this paper are as follows:

1. To summarize the major concepts and trends of smart city, vertical greening and new greenhouse technologies and approaches by reviewing relevant subjects of research that focus on those factors of water saving, green energy management, natural ventilation and system integration, which make progressive greenhouses the possibility of becoming more sustainable and smart-green.
2. To present a novel prototype of a green-energy, water-autonomous greenhouse system that is mainly dependent only on solar energy, having a considerable reduction in water use due to closed-cycle water recycling inside the greenhouse and with the recovery of evapotranspiration-condensation, and by integrating networking solutions converging smart-green technologies.
3. By discussing the innovations and advantages, to reveal that the proposed GEWA system (green-energy water-autonomous greenhouse system), which was developed by an increasingly sophisticated and multi-disciplinary approach, has become a more responsive, efficient, and performative fit for an alternative-technology approach towards sustainable, smart-green vertical greening in smart cities.
4. To suggest the usage of a true Building Information Modeling (BIM) model for further design of the proposed greenhouse system to allow us to build a smart-green point cloud with a BIM workflow on any network in a smart city.

2. LITERATURE REVIEW

2.1 New generation greenhouses

For overcoming drought, the Cycler Support Guide (Buchholz, 2008) aimed to investigate the potential of growing food using a base of unconventional water sources so as to describe a long term scenario including a new generation of water efficient greenhouses. A group of new greenhouse technologies allows collecting condensed water from air water vapor within greenhouses. By using this kind of much less conventional water, together with harvested rainwater, it is possible to reach a water autonomous irrigation situation in many regions of the world. A major point is that the natural water cycle can be circumvented and water efficiency can be drastically improved through the use of new greenhouse technologies. They outline that a greenhouse could “provide condensed water regained after being evaporated by plants with recycling rates of up to 80% and reduced water consumption compared to open field intensive production of 95%”. In the Cycler Support Guide, five new generation greenhouse model research areas are proposed, including: (1) closed greenhouse for food, (2) closed greenhouse for non-food crops including greenhouse integrated solid state fermentation, (3) open greenhouse with natural convection, built on mountain slopes, using saline water from the sea for evaporative cooling, integrated aqua farming for fish and algae production using waste water and solid waste from fish procession, (4) model urban area for wastewater pre-selection in urban areas with use of greywater in greenhouse projects, and (5) concentrated solar power projects with cooling water recycling in closed greenhouses (Buchholz, 2008).

The Naples event of the Greensys 2007 symposium (Giacomelli, 2007) demonstrated that room for improvement in greenhouse cropping is evident. In Naples, the main focus was on a famous closed greenhouse prototype named Watergy Regarding innovation in greenhouse engineering, Giacomelli (2007) points out in his address that: (1) greenhouse components and designs directly impact on crop growth; (2) correctly assessing the importance of crop-greenhouse interactions is needed; (3) real-time measuring of a maximum number of parameters is necessary; and (4) other than the Watergy project, engineers have to find the ways and means to substantially reduce energy and water use and to ensure that an acceptable return on investment can be achieved when high enough yields are produced. In the opinion of Prof. Stefania De Pascale, convener of Greensys 2007, a greenhouse system is in some respect already an energy-saving system compared to open field agriculture and is an excellent environment to achieve an optimal balance between an efficient environmental control and an efficient plant use of the available resources (Giacomelli, 2007).

2.2 Watergy project

Research for the Watergy project was funded by the European Union’s 5th Framework Program promoting Energy, Environment and Sustainable Development (Zaragoza, Guillermo et al., 2007).

The Watergy project proposes two prototypes utilizing the application of a novel humid-air solar collector. The first is constructed in Almeria (Spain), and it is a closed greenhouse for solar thermal energy capture, water recycling, water desalination and advanced horticulture use. The second is constructed in Berlin (Germany), and it is a greenhouse with an autonomous supply of heat and also of clear water, and is connected to the building and purifies its residual grey water. In the context of sustainable architecture, the Watergy system means that this concept of zero energy is complemented with that of water autarchy. This autonomous and local way of treating urban residual water means that, on one hand, the decentralization of an urban water supply can be processed with self-sufficient systems able to close the water cycle locally, and on the other hand, intensive agriculture can be freed from its enormous consumption of water. The concept of solar collectors is that humid air allows the storing of more thermal energy at a given temperature and the same amount of energy can be transported by a much lower air volume flow, sustained by natural buoyancy, while the evaporation and condensation processes increase the efficiency of the heat transfer (Zaragoza, Guillermo et al., 2007).

The Watergy project was widely discussed in the context of many subjects of research, including: (1) thermal control for optimized food production and greywater recycling by a new solar, humid-air collector system; (2) the functioning of such a system for solar thermal energy collection, water treatment and advanced horticulture (Zaragoza, Guillermo et al., 2005); (3) using the simulation environment 'Smile' to simulate thermal and fluid dynamical processes including water interactions between plants and air (Jochum & Buchholz, 2005); (4) describing passive cooling and dehumidification strategies (Buchholz et al., 2006); (5) critical discussion following the results of EI Ejido in Almeria, Spain (Zaragoza, G & Buchholz, 2008); (6) exploring a suitable method to provide required automatic adaptation to an adaptive model for greenhouse control (Speetjens, Stigter, & Van Straten, 2009); and (7) developing a physics-based model, based on enthalpy and mass balances, to predict the new solar, humid-air collector system's behavior (Speetjens, Stigter, & van Straten, 2010).

2.3 Water saving

Water saving concepts have been discussed in many subjects of research, including: (1) that novel high technological solutions in greenhouse production can lead the way to highly efficient water use production techniques, which can alleviate the water shortage problem (van Kooten, Heuvelink, & Stanghellini, 2008); (2) the technical aspects and results of a trial using a fully closed greenhouse showing advantages in reduction in energy, water and chemical crop protection (Opdam et al., 2005); and (3) compared to irrigated crops outdoors, the seasonal evapotranspiration of greenhouse horticultural crops is relatively low due to the lower evaporative demand inside the greenhouse (Orgaz et al., 2005).

2.4 Energy management

Energy management concepts have been discussed in many subjects of research, including: (1) that final energy efficiency is determined by improvements in energy conversion, reductions in energy use for environmental control and the efficiency of crop production, and the development range from new modified covering materials, innovative and energy conservative climate control equipment and plant response based control systems to integrated energy efficient greenhouse designs (Bakker et al., 2008); (2) where the greenhouse system was treated as a solar collector having an absorber plate (the greenhouse soil) and a cover system consisting of three semi-transparent parallel layers (the greenhouse cover, the humid air and the plants), and that there are some general methods for estimating the amounts of solar energy absorbed by the greenhouse components and lost to outside the greenhouse (Abdel-Ghany & Al-Helal, 2011); (3) an energy management concept to maximize the utilization of solar energy through seasonal storage by removing excess sensible and latent heat because of no ventilation in a fully closed greenhouse, and although higher amount of solar energy can be harvested in a fully closed greenhouse, in reality, a semi-closed greenhouse concept may be more applicable (Vadiee & Martin, 2012); (4) many thermal energy storage systems, like TES, UTES, SCW, PCM and BETS, could be considered as seasonal storage or short term storage, and a theoretical model could be developed to carry out energy analyses (Vadiee & Martin, 2013); and (5) fluorescent solar concentrators, photoselective and other materials could be considered to be solar radiation manipulations in greenhouse claddings to provide advantages for plants (Lamnatou & Chemisana, 2013).

2.5 Natural ventilation

Natural ventilation concepts have been discussed in many subjects of research, including: (1) relative to a naturally ventilated greenhouse, wind direction significantly affects the flow patterns both inside the greenhouse and at the roof openings, also affecting the ventilation rate and the air and crop temperature distributions (Teitel et al., 2008); (2) excessively high internal temperatures have negative effects on the yield and quality of almost all greenhouse crops because that ventilation is generally insufficient, and the reduced CO^2 levels and the creation of high humidity adversely affects inside air composition, and condensation on the cover also reduces the transmission of solar radiation (Parra et al., 2004); (3) to maximise ventilation when wind speeds are low, buoyancy-driven ventilation and combined roof and sidewall ventilation should be used (Baeza et al., 2009); and (4) there is a unique relationship between water use efficiency and the coupling of the greenhouse environment to the outside air, increasing the capacity of the cooling system could reduce ventilation needs of semi-closed greenhouses and so increase water use efficiency (Katsoulas et al., 2015).

2.6 New approaches of technology

New approaches of greenhouse technology have also been discussed in many subjects of research, including: (1) all three geographic areas of Northern Asia share the need of having optimized climate control based on crop response to the greenhouse environment. For more efficient greenhouses, the progress in Northern Asia is toward greenhouses being solar collectors and to develop new heating strategies. Important subjects addressed in the Netherlands are energy conservation and increasing mechanisation, and in the Mediterranean there is growing interest in semi-closed greenhouses with CO^2 enrichment and control of excessive humidity (Montero et al., 2011); (2) to achieve a sustainable greenhouse that is energy neutral, consumes only the essential amount of water, and has minimal negative environmental impact, recent years have witnessed the development of photovoltaic cells for power generation, insect-proof screens, and the use of tools of computational fluid dynamic (CFD) simulations to investigate the effects of structure shape, ventilator size and arrangement of microclimates (Teitel, Montero, & Baeza, 2012); (3) the contribution of a low energy concept by combining energy saving methods with an improved control of greenhouse microclimate, and also by improving the cropping system and using new cultivars, so that the closed greenhouse can be developed and propagated as an energy producing greenhouse, and that the greenhouse should be operated semi-closed to improve the use of solar energy for heating (Tantau et al., 2011); and (4) passive greenhouses using only renewable energy sources, such as geothermal, wind and solar, by means of cool water heat pumps, wind turbines and photovoltaic panels, are thereby fully free of any energetic infrastructure and can be installed in remote areas, so offer a fundamentally sustainable agricultural resource and a global ecological reconstruction opportunity (Balas, 2014).

2.7 Vertical greening technology

Finally, the following research reveal the contributions and constraints of vertical greening in the urban environment.

Misni, Baird, and Allan (2013) studied the potential impact of shade trees and different types of foliage on the thermal performance of houses and found that well-designed landscaping around houses could potentially reduce heat build-up, by shading, evapotranspiration, and wind channelling, by as much as 3^{oC}.

Lin and Huang (2013) reviewed potential environmental benefits and an applied experience in Taipei city and found that vertical greening has made a significant contribution to landscape beautification in Taipei.

Peng (2013) studied the relationship and development between vertical greening and greening buildings and focused on vertical greening technology and innovations for increasing green space, creating urban green networks and applying vertical greening to urban rehabilitation and maintenance.

Peng, Kuo, and Lin (2015) proposed a fiber reinforced plastic vertical greening system and a way of arranging plants in groups, natural irrigation, and a rainwater recycling system to encourage the use of vertical greening in urban rehabilitation and to improve sustainability of the environment in Taiwan.

According to Hemming et al. (2014), in Taiwan, open field vegetable production is threatened by subtropical climatic disasters, such as high wind speeds and heavy rainfall, which can cause the destruction of whole crops. Also, the vegetable production is threatened by pests and diseases resulting in a high need for pesticides, and the greenhouse production systems are able to provide protection for the crops.

3. GREEN-ENERGY, WATER-AUTONOMOUS GREENHOUSE SYSTEM

3.1 A novel prototype of a green-energy, water-autonomous greenhouse system

The presented novel prototype of a green-energy, water-autonomous greenhouse system has been patented as an invention in Taiwan for a period from 2015-03-21 to 2031-08-24. The patent number is I-477230.

3.1.1 Summary of the prototype

The objective of the present prototype is to provide a green-energy, water-autonomous greenhouse system, wherein the system can be installed in suspension outside a window in order to automatically supply electric power for its internal operations by means of the solar power generation device configured therein, such that a plant ecological environment system, similar to a greenhouse, can be maintained within the window box.

The solar power generation device converts absorbed light energy into electric energy to drive the thermoelectric cooling chip board's operation, and the operations of the thermoelectric cooling chip board can reduce the surrounding temperature, thereby generating condensed water to drop irrigate the plants cultivated in the plantation trough. In addition, the sunlight illumination further causes the temperature in the system to rise up such that the water molecules within the system may evaporate, and wet, warm air is continuously heated and humidified, ascending by way of its natural buoyancy and with the assistance from the air circulation enhanced by a built-in ventilation device; as such, a plant ecological environment system can be achieved by way of this continuous circulation process.

3.1.2 Detailed descriptions of the preferred embodiments

The aforementioned and other technical contents, aspects and effects, in relation to the present prototype, can be clearly appreciated through the detailed descriptions concerning the preferred embodiments of the present prototype in conjunction with the appended drawings, shown in Section 3.1.3.

Refer initially to *Figure 1, objects 1, 2A, 2B, 3A* and *3B*, wherein a stereo combinatorial structure view, a front stereo view, a rear stereo view and a lateral view for a green-energy, water-autonomous greenhouse system, according to the present invention, are respectively shown. From the figures, it can be seen that the system (1) comprises a frame body (11), having a plantation trough (16) installed at the bottom; a solar power generation device, installed at the top of the frame body (11) (and including a mono-crystalline silicon solar photovoltaic panel (121) and a battery (122)); a thermoelectric cooling chip board (13) (which includes a plurality of thermoelectric cooling chips (131) and a condensing media (132)); and at last a window body structure (14) installed on the frame body, wherein the front, rear, left, right and upper frames of the frame body (11) all allow the installation of at least a window body structure (14). In addition, the thermoelectric cooling chip board (13) is installed on the upper side within the frame body (11), the solar power generation device is installed on the top of the frame body (11), and the solar power generation device is connected to the thermoelectric cooling chip board (13) by way of the battery (122), so as to provide electric power for the operations of the thermoelectric cooling chip board (13).

In addition, it can be seen from *Figure 1, Objects 1, 2A* and *2B*, that the frame body (11) includes a front frame, a rear frame, a left frame, a right frame and an upper frame, and the window body structure (14) is installed on the front frame, the rear frame, the left frame, the right frame or the upper frame of the frame body (11). Herein, the window body structure (11) may be a manual pushed-out window, an electric projected-out window or a fixed window, so that in case the window body structure (11) is a manual pushed-out window or an electric projected-out window, as shown in *Figure 1, Objects 1 2A, 2B* and *3B*, it can be pushed outward to open in order to perform air circulation for the interior of the system (1). Furthermore, a solar photovoltaic chip can be additionally installed within the window body structure (14) thereby acting as a splitter or dimmer glass to regulate and control the power supply, and the solar photovoltaic chip may be Copper-Indium-Gallium-Selenide (CIGS) solar cells.

Also, the window body structure (14) in the front frame, left frame or right frame of the frame body (11) may include a prism sheet splitter glass or a dimmer glass.

Moreover, a condensing media (132) may be placed under the thermoelectric cooling chip board (13) such that the cooling terminal of the thermoelectric cooling chip board (13) can reduce the temperature and generate condensed water on the condensing media (132).

Additionally, the solar power generation device may include a mono-crystalline silicon solar photovoltaic panel (121) and a battery (122), and the battery (122) is connected to the mono-crystalline silicon solar photovoltaic panel (121) and the thermoelectric cooling chip board (13), wherein the interior of the mono-crystalline silicon solar photovoltaic panel (121) includes a solar photovoltaic chip which can be mono-crystalline silicon solar cells.

Yet also, at a minimum, a heat recycle dehumidification ventilation device (151 and 152) can be additionally installed in the system (1) so that these heat recycling dehumidification ventilation devices (151 and 152) are capable of providing the features of inward air dehumidification, heat exchange and ventilation, wherein the heat recycle dehumidification ventilation device (151) may be set up between the mono-crystalline silicon solar photovoltaic panel (121) of the solar power generation device and the frame body (11), and the other heat recycle dehumidification ventilation device (152) installed between the frame body (11) and the thermoelectric cooling chip board (13).

Furthermore, as shown in *Figure 1, Object 4*, the plantation trough (16) can include the vegetation media (161) and at least a plant (162), wherein the plant (162) may be an ornamental plant or an edible plant, the plantation trough (16) may be a light porous moisture-retentive vegetation media trough and the vegetation media (161) may be a soil or porous moisture-retentive media. Also, a siphon (163) can be connected between the vegetation media (161) in the plantation trough (16) and the water storage container (172).

In addition, it can be observed from *Figure 1, Object 4*, that at least two water storage containers (171 and 172) can be added to the inside of the frame body (11), wherein a water storage container (171) can be placed under the thermoelectric cooling chip board (13) and the other one placed beneath the vegetation media (161) of the plantation trough (16), in which these two water storage containers (171 and 172) are connected by way of a water pipeline (18) so as to transfer water held in the water storage container (171) into the water storage container (172).

Next, it can be seen from *Figure 1, Object 4*, that a recycle pipeline (not shown) as well as an inlet (19) can be additionally installed in the system (1), wherein the recycle pipeline facilitates the recycle usage of condensed water or rainfall, and an end of the inlet (19) is connected to the water storage container (172) under the vegetation media (161) in the plantation trough (16), such that the user can also manually irrigate via the inlet (19).

In addition to the above-said implementations, other devices can also be configured to the system (1) according to the present prototype. For example, an electronic supervisory system (not shown) may be alternatively connected into the system (1) such that the electronic supervisory system can have control over the window body structure (14) and the thermoelectric cooling chip board (13). Furthermore, a ventilation device capable of ventilation amount adjustments (not shown), a thermo-hygrometer capable of detecting the temperature and humidity in the system (1) (not shown) or a barometer capable of detecting air pressure values in the system 1 (not shown) can be additionally installed.

The electronic supervisory system can further control the ventilation device, the thermo-hygrometer or the barometer such that the user can remotely monitor the environmental variations within the system (1) and control the ventilation device so that the ventilation device can automatically adjust the states of air speed, air withdrawal and air exhaustion in order to adjust the temperature in the system (1). What is more, the electronic supervisory system also allows the user to remotely monitor the environmental variations in the system, and the electronic supervisory system can control the window body structure to open or close automatically and manipulate the thermoelectric cooling chip board (13) to adjust the internal temperature.

Consequently, as shown in *Figure 1, Object 4*, when the sunlight (2) illuminates the mono-crystalline silicon solar photovoltaic panel (121), the solar power generation device converts absorbed light energy into electric energy and transfers electric power to the thermoelectric cooling chip board (13) as well as to the ventilation device (not shown); therefore, when the thermoelectric cooling chip board (13) operates, the cooling end of the thermoelectric cooling chip (131) in the thermoelectric cooling chip board (13) can reduce the temperature and condensed water created by means of the condensing media (132), which can drop down due to gravity and irrigate the plant (162) in the plantation trough (16). Meanwhile, because the sunlight (2) illuminates the system (1), the internal temperature may increase and the potential energy difference between the plant (162) and the vegetation media (161) (e.g., soil) in the plantation trough (16) causes water molecules to evaporate and rise up to the top, and the air circulation can be enhanced with the ventilation device, such that the wet, warm air can be continuously heated and humidified in order to ascend, thereby achieving a plant ecological environment system capable of autonomous circulations by means of this continuous circulation process.

3.1.3 Brief description of the drawings

Figure 1 shows the drawings and major component symbol descriptions include a stereo combinatorial structure view, a front stereo view, a rear stereo view, two lateral views, an operation diagram, and an embodiment diagram for a green-energy, water-autonomous greenhouse system according to the present invention.

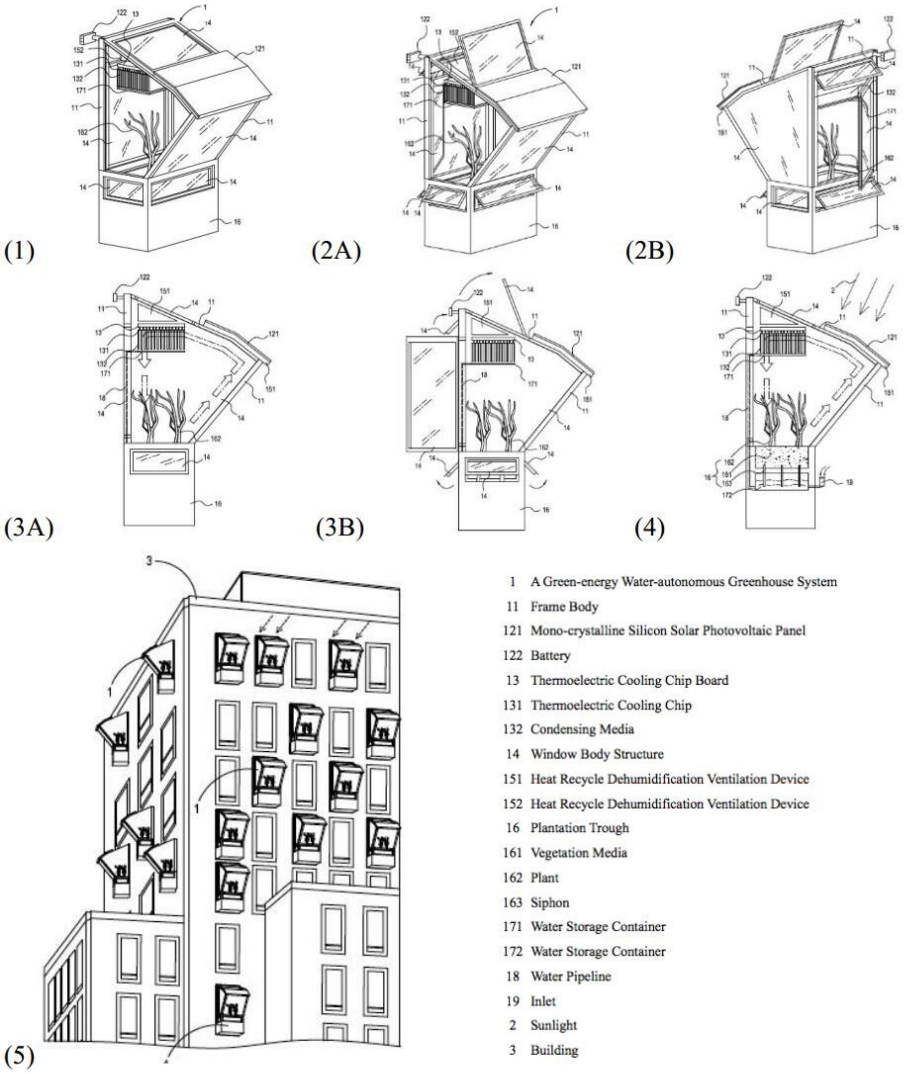

Figure 1. Drawings and major component symbol description

4. DISCUSSION

4.1 Innovations

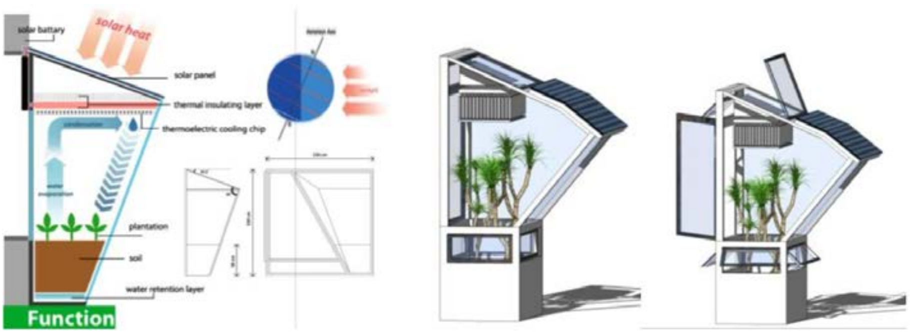

Figure 2. Innovations in system

Figure 2 shows the diagram of system function and a symbol picture according to the present invention.

Innovations in the presented prototype of the green-energy, water-autonomous greenhouse system are pointed out as follows:

1. "A system is a set of things… interconnected in such a way that they produce their own pattern of behavior over time. The system may be buffeted, constricted, triggered, or driven by outside forces. But the system's response to these forces is characteristic of itself, and that response is seldom simple in the real world. A system is more than the sum of its parts; it may exhibit adaptive, dynamic, goal-seeking, self-preserving, and sometimes evolutionary behavior" (Meadows, 2008). Just like the system defined above, the green-energy, water-autonomous greenhouse system (simply named GEWA), interconnected by a set of elements showed in Figure 1 and Figure 2, is indeed a coherently organized system that achieves an adaptive eco-environment.
2. The system's characteristic key functioning is started with the using of a thermoelectric cooling chip board on the basis of the Peltire effect, which makes it possible for the evaporation and condensation processes for a small water cycle to be completed inside the greenhouse, and an autonomous water supply to be accomplished.
3. GEWA is an enhancement on the sophisticated and multidisciplinary approaches and technologies mentioned in most of the reviewed research subjects and tries to achieve an adaptive, semi-closed climate-responsive, passive greenhouse system with the following points of invention:

(1). There is an automatic supply of electric power for the internal operations by means of a solar power generation device installed at the top of the frame body. The solar power generation device is connected to a thermoelectric cooling chip board by way of a battery to provide electric power to drive it to reduce the surrounding temperature, thereby generating condensed water.

(2). The condensed water was phase-changed by evapotranspirated water vapors, which ascend with sunlight-illuminated wet warm air by natural buoyancy.

(3). An electronic supervisory system can be connected, thereby allowing control over the operation of a window's open-closure and illumination adjustments, the thermoelectric cooling chip board, the ventilation device, the heat recycle dehumidificator, the hygrometer, the thermometer, the barometer and other measuring.

4. The special integrated mechanism applied in the system includes: (1) the photovoltaic effect of the solar power system; (2) purification of water; (3) photocatalysis on the surface of structure and materials, equipment and devices; (4) a fuzzy control strategy for the climatic sensor system; (5) the photoelectrochromic effect of window glass; (6) prism sheet splitter glass; and other intelligent automations.
5. The GEWA will be developed as a cyber physical system.

4.2 Advantages: in the general system

Compared with other conventional application technologies, GEWA further offers the following advantages:

1. A plant ecological environment system that can be maintained autonomously by the system.

2. The window of the present prototype facing indoors can be opened to supply the generated oxygen into the room, thereby attaining the purposes of green environment and beautification effects, and the people within the room can also enjoy the delightful view.

3. The present prototype can be installed extending outwards from a window, does not occupy indoor space and is very convenient to arrange. Meanwhile, such an outside-window installation can be helpful for adding suitable ornamental plants or alternatively practicing edible plant vegetation to act as a small-sized vegetation farm.

4. Environmental variations within the system can be monitored remotely by an externally connected electronic supervisory system and the changing environmental factors can be controlled and suitably regulated to maintain an optimal growth environment for plants.

4.3 Advantages: Interaction across a building system

A GEWA, as an eco-environment, could have many interactions across a building system. It could be an experimental platform, a climate station, a cloud point, and indeed be a third environment in between the outside and interior building environment. Being a third environment, GEWA could be more adaptive than conventional vertical greening by its additional function of mitigating environmental impact to a building. It could become a cyber physical system.

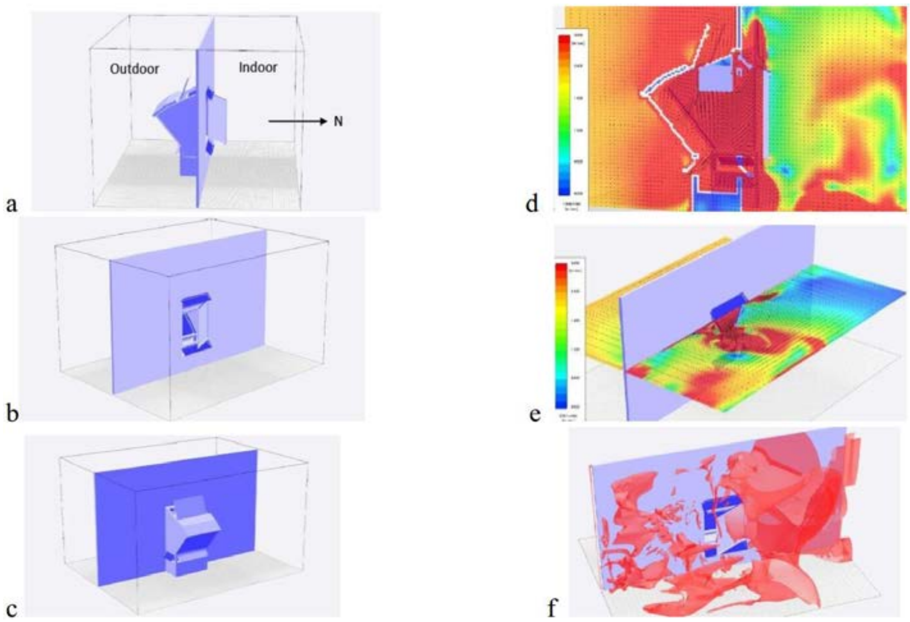

Figure 3. CFD environmental simulations of wind flow through greenhouse (simulated by WindperfectDX., Total number of grid points is 2,753,520)

An example is described by a CFD simulation investigating the influence of GEWA on the wind flow from the outside to the inside of the building. As shown in *Figure 3,* a wind flow with an average wind speed of 2.43m/s with a SW wind direction was simulated, *Figure 3, Objects a* to *c*, show a CFD model and a grid pattern with 2,753,520 computating grids. *Figure 3, Object d* shows the windflow section at Range: 0~3m/s, *Object e* shows windspeed distribution at 1.5m high at Range: 0~3m/s, *Object f* shows the windspeed equalizer surface at windspeed 1m/s. From the results of the analysis, the windflow pattern could be realized and the effects on the environment could be evaluated.

Other environmental factors and parameters like temperature and humidity could also be simulated.

4.4 Advantages: Incorporating greenery into a building

Figure 4. Incorporating greenery into a building, before and after.

Figure 4 shows an example of incorporating GEWA into the Mega Holdings Building, Taipei using a real 'before' photograph and an 'after' simulation photograph.

A GEWA could incorporate a variety of greenery into buildings on the walls and openings; it could be a window garden, a sky garden or a vertical farm. It could develop a vertical greenery networking system in a smart city.

It is expected that GEWA will be used to incorporate greenery into a building as an alternative of vertical greening, in order to open a very interesting possibility for increasing attractiveness of cityscapes and to enhance progressive urban revitalization in smart cities.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

A sophisticated and multi-disciplinary green-energy, water-autonomous greenhouse system, by using the water resource and solar energy in a rational way to aim at more well-being based on more products, more information, more services, and more experience, could be an alternative-technology approach towards a sustainable smart-green vertical greening in smart cities.

Aimed at improving responsiveness, conservation, efficiency and performance for environmental sustainability, resource sustainability, and material and technological sustainability, and also aimed at achieving better well-being, GEWA is expected to be a foresight with simplicity in evolution.

5.2 Recommendation

The following studies are suggested for future research:

1. A real model of the prototype should be established to conduct a relevant experimental study and to contribute big data for research.
2. A foresight design based on Building Information Modeling (BIM) is necessary to provide advanced understanding of the proposed greenhouse system and to allow the building of a smart-green point cloud with BIM workflow on any network in a smart city.

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International review for spatial planning and sustainable development, Vol.5 No.1 (2017), 71-85
ISSN: 2187-3666 (online)
DOI: http://dx.doi.org/10.14246/irspsd.5.1_71

An Integrated Model of Transportation and Land Use for Development and Application in Beijing

Yu Zhang[1*], Xiaodong Zhang[1], Meng Zheng[1], Ying Long[2]
1 Beijing Institute of City Planning and Design
2 School of Architecture, Tsinghua University
** Corresponding Author, Email: zy_jts@aliyun.com*

Received: March 02, 2016; Accepted: June 15, 2016

Key words: Beijing, Land-use and Transportation Integrated Model, Development, Application

Abstract: Supporting the evaluation of Beijing Urban Master Planning (2004-2020), a Beijing land-use and transportation integrated model is established on the basis of the transportation model of Beijing. The core improvement is the addition of a land use model and the interaction between the land use model and a transport model. Four sub models (location choice, rent, development and land price models) are contained in the land use model. The most important sub model is the location choice model. Commute accessibility, education, culture, environment and health care factors are selected to calibrate this model. The population distribution is sourced from the location choice model and the commute accessibility has been computed based on the transport model and input into the land use model.

1. INTRODUCTION

Beijing Urban Master Planning (2004-2020) was compiled in 2004 and has been implemented over nearly 15 years. The Beijing metropolitan area has been rapidly developed under the guidance of the spatial strategy concept called "Two Axes, Two Belts and Multiple Centers" proposed in the Beijing Urban Master Planning. Looking back at the changes in recent years, the comprehensive transportation system planning with a focus on the development of a rail transit system has played a key role in the fulfilment of the "Two Axes, Two Belts and Multiple Centers" ideology. Although the concept of the integrated planning of land use and transportation has been widely accepted and reflected in major projects in Beijing recently, the degree of coordinated development between land use and transportation in Beijing has never been evaluated in a quantitative manner.

The development purpose of this model is to find out the interaction rules between three systems, the economic, land use and traffic systems, in order to establish relevant integrated models with which to study the macro rules across these three urban sub systems through quantitative analysis and the study of micro individual behaviors under the conditions of a market economy.

The specific approach of this paper is to establish a simulation model to reflect the interactive relationship between transportation and land use under a certain economic background by exploring the patterns of several major individual choice behaviors including residential location choice and real estate development.

1.1 Literature review

In recent years, research reports on the interactive relationship between transportation and land use have explored quantitative evaluations of transportation and land-use integrated planning in major cities around the world. For example, cities such as Charlotte, Seattle and Los Angeles in the United States have used PECAS (Hunt & Abraham, 2009; Wegener, 1994; Abraham, Garry, & Hunt, 2005) and other relevant software to build transportation and land-use integration models. In addition, Paris (Waddell, 2002, 2001) uses UrbanSim to build its transportation and land-use integration model. Mexico City applies Tranus to build its transportation and land-use integration model (de la Barra, 1989). Shenzhen also tends to use Tranus to build its own integration models. In addition, universities and institutions including Tsinghua University, Peking University and the Beijing Transportation Research Center are conducting relevant explorations and research on transportation and land-use integration models. However, there is currently still no matured transportation and land-use integration model successfully developed and applied in the planning practice of mainland China because of a lack of data.

1.2 Previous related research on Beijing

A macro transportation strategic model of Beijing (BMI model) is a macro transportation strategic module of the Beijing metropolitan area, which is built-up by the Beijing Municipal Institute of City Planning and Design and MVA in 2008 (Beijing Municipal Institute of City Planning and Design & MVA, 2008), according to relevant data obtained from a Transportation Survey in 2005. In this model, Beijing is divided into 178 Traffic Analyse Zone (TAZ). The model dimensions include two family type categories, 'car available' families (CA) and 'no car available' families (NCA). Five different types of trips are considered in this model: home-based work (HBW) trips, home-based school (HBS) trips, home-based other (HBO) trips, non-home-based (NHB) trips and employment-based (EB) trips. The five modes used in the model are bike, car, taxi, bus and metro. The specific structure of the model is shown in Figure 1.

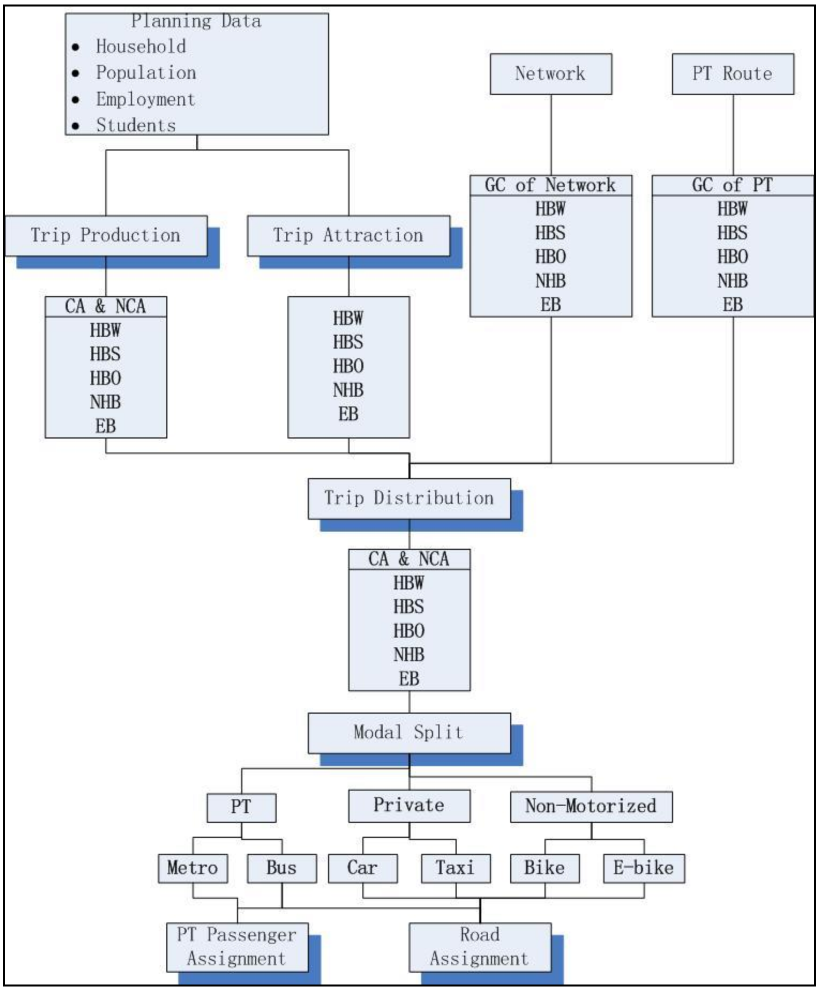

Figure 1. Frame Diagram of BMI Model Structure

The set-up of the BMI model has laid a transportation sub-model foundation for the building of the transportation and land use integrated model.

The land use sub model design and calibration of the Beijing transportation and land use integrated model will be discussed below.

2. MODEL DESIGN

2.1 Model framework

The actual market behaviors of Beijing are analyzed according to the available data foundation based on the above-mentioned development purpose. The research framework of the transportation and land use integrated model is shown in Figure 2.

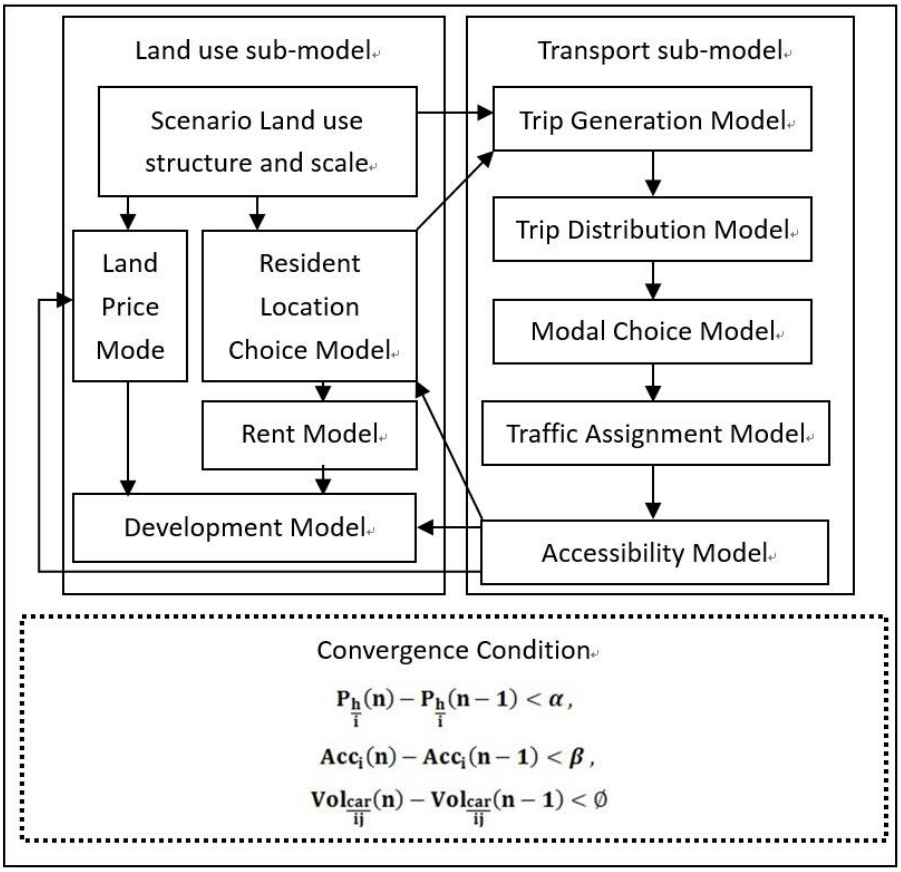

Figure 2. Flow Chart of Beijing Land Use and Transport Integration (BLUTI) Model Framework

Figure 2 indicates that the land use model in this transportation and land use integrated model takes the residential real estate market and resident location choice as research objects for model establishment without putting location choice behavior for enterprises into consideration. The main reasons are listed as follows.

The current investigation of location choice behaviors for enterprises is relatively insufficient and the accuracy of data available has to be checked.

The enterprise scales differ greatly and it is relatively difficult to select an enterprise model analysis unit.

There are relatively abundant policy-dominating factors in the industrial market of Beijing.

Therefore, the location choice for enterprises is assumed as an exogenous variable in this transportation and land use integrated model (the current year is mainly based on an economic census while the planning year mainly applies the relation coefficient of planned land use and jobs as the calculation basis) to simulate the market behaviors of the residential market.

The land model and the transportation model interact with each other primarily according to the transportation accessibility of different zones obtained from the transportation accessibility calculation model and the residential distribution conditions of different types of households provided by the location choice model for residents.

The model convergence is mainly decided by three factors:

1. The difference of traffic volume between each loop is within the present threshold scope;

2. The difference of population between each loop is within the present threshold scope;

3. The difference in terms of accessibility between each loop is within the present threshold scope.

Under the precondition of the satisfaction of the above-mentioned three convergence conditions, the model can be assessed as convergent and relevant results can be obtained.

Figure 3 indicates that there are mainly four sub-models involved in the land use model. They are the location choice model for residents, the leasing model, development model and land price model. The relationships amongst these four sub-models are shown in Figure 3.

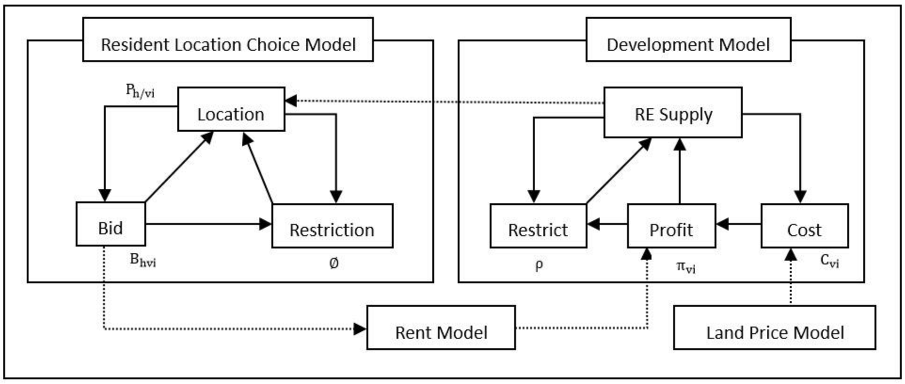

Figure 3. Flow chart of calculation relations of land use sub-model

Based on the model, the accessibility calculation model should also be clearly made to realize the interactions between the transportation model and land use model.

2.2 Model Dimensions

Combining the relevant data of Beijing and the dimension conditions of the existing transportation model, the dimensions of the land use model are divided into the following three parts.

1. Family Classification

The family classification is subdivided into five types based on the original transportation model classification and family differences in residential location choice. The five types of family include low-income family, medium-income family with car, medium-income family without car, high-income family with car and high-income family without car.

2. TAZ

The division of transportation zones continues to use the method stipulated in the existing macro transportation model. A total of 198 transportation zones are used (178 inner zones).

3. Division of Land Use Types

Since this model is only targeted at the residential real estate market and there is a relative shortage of basic data of the residential land use, the land use is categorized as one type, regular residential land use.

3. SUB-MODEL DESIGN AND CALIBRATION

3.1 Residential Location Choice Model

The residential location choice model is mainly based on the behavior of competitive lease prices in the real estate market. In other words, the leasing or purchasing group in residential real estate is the highest bidder. The distribution proportions of various kinds of groups in the residences in each location and such groups' willingness to pay (WTP) for such residences can be worked out through the calculation of this model (Goulias, 2003).

This model is a multi-Logit model based on the dispersal of choice behavior. The parameter calibration process is as follows.

1. Analysis of Dependent Variable House Price Distribution Samples in Base Year

The spatial interpolation method is used to obtain the house prices of the regular residences and apartments of each community model in the base year (2005) according to 626 samples investigated by the research group in 2005 as indicated in Figure 4.

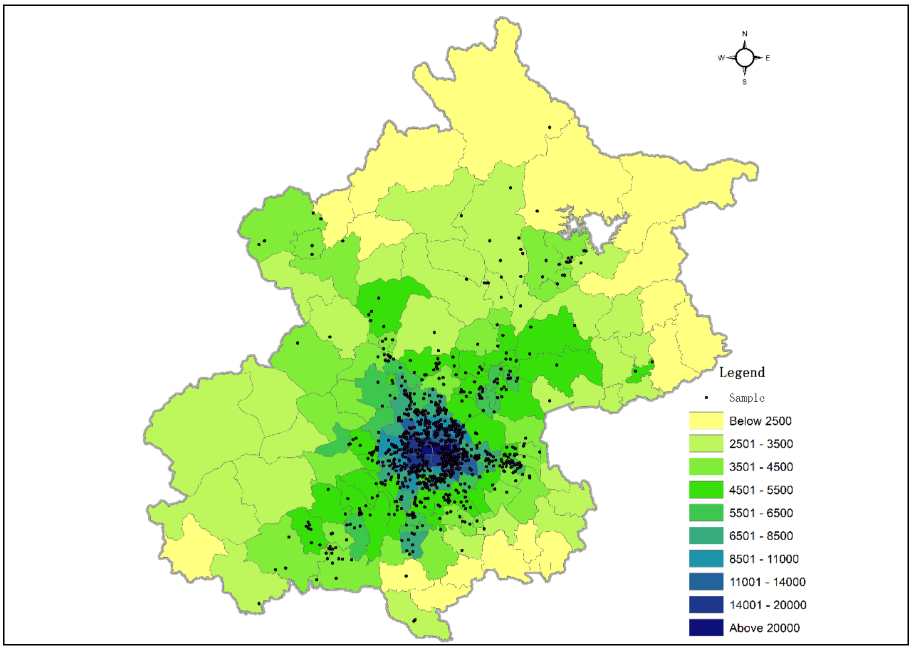

Figure 4. Distribution diagram of resident real estate price in Beijing in 2005

2. Selection of Independent Variables of the Model

According to the characteristics of the location choice of residents in Beijing and through the qualitative investigation and analysis, residents will mainly consider the following factors when selecting their locations.

The first factor is the convenience of daily commuting, and location accessibility is used as an independent variable in the model.

The second factor is distribution of education resources around the location. Distance from the transportation zone to any of the top-50 primary and middle schools is taken as an independent variable.

The third factor is the living environment around the location. The distance from the transportation zone to the nearest scaled university campus is taken as a variable.

The fourth factor is the natural environment around the location. The distance from the transportation zone to the nearest park or greenbelt is taken as a variable.

The fifth factor is the medical environment around the location. The distance from the transportation zone to the nearest top-grade hospital is taken as a variable.

The independent variables of parameters selected in the residential location choice model are summarized in Table 1:

Table 1. Six independent variables of parameters in the residential location choice model

Independent Variable	Definition	Unit
PriDist	Nearest distance from the centroid of the transportation zone to any of the top-50 primary schools in Beijing	Km
MidDist	Nearest distance from the centroid of the transportation zone to any of the top-50 middle schools in Beijing	Km
ParkDist	Nearest distance from the centroid of the transportation zone to any of the 53 city parks registered in Beijing	Km
UniDist	Nearest distance from the centroid of the transportation zone to any of the 54 universities with a campus area exceeding 10 hectares in Beijing	Km
HospDist	Nearest distance from the centroid of the transportation zone to any of the third-level and grade-A hospitals in Beijing	Km
Acc	The location accessibility of the transportation zone can be expressed by distance from the location to the employment area in terms of convenience.	——

In addition to these six independent variables, the scale independent variables, such as the total number of each family type, are introduced in the residential location choice model to reflect the proportional differences of different family types in the model. This is due to the use of lease-bidding theory with the purpose of better revealing the influence of the change of scales of various family types in the planning year on the residential location choice model.

3. Parameter Calibration of the Model

Based on the Multinominal Logit Model (MNL) model, the format of the utility equation of the residential location choice model is as follows:

$$B_{hvi} = Asc_h + \alpha \times \ln(Scl_h) + \beta_h \times PriDist_i + \gamma_h \times MidDist_i + \delta_h \times ParkDist_i + \rho_h \times UniDist_i + \sigma_h \times HospDist_i + \theta_h \times Acc_i + \varepsilon$$

Where,

B_{hvi} represents the WTP of group *h* for class-*v* real estate type in transportation zone *I*;

Asc_h represents a constant of WTP function of group *h*. The value is to be calibrated.

Scl_h represents the population scale of group *h*;

The independent variables of the remaining WTP functions are shown in the above table.

α \ β_h \ γ_h \ δ_h \ ρ_h \ σ_h \ θ_h is the parameter to be estimated while ε represents a random independent variable.

According to the equation, BIOGEME (Bierlaire, 2003) has been used to carry out model calibration after independent variables, *i*, are standardized. The standardization of independent variables is shown in Table 2:

Table 1. Parameter list of the calibration results of the residential location selection model

Family type	Asc_h	α	β_h	γ_h	δ_h	ρ_h	σ_h	θ_h
1. Low-income family	0	0.68	-0.0047	-0.46	-0.37	-0.58	-0.0006	0.473
2. Medium-income family without car	-0.081		-1.05	-0.678	-1.56	-0.62	-1.17	1.27
3. Medium-income family with car	0.28		-0.123	-1.2	-0.47	-0.74	-0.624	0.467
4. High-income family without car	-0.60		-2.05	-1.29	-1.36	-1.69	-1.75	1.28
5. High-income family with car	-0.52		-1.77	-1.37	-1.24	-1.37	-1.66	1.17

The estimated values in the base year of the abovementioned calibration results and the observed values are compared in Figure 5.

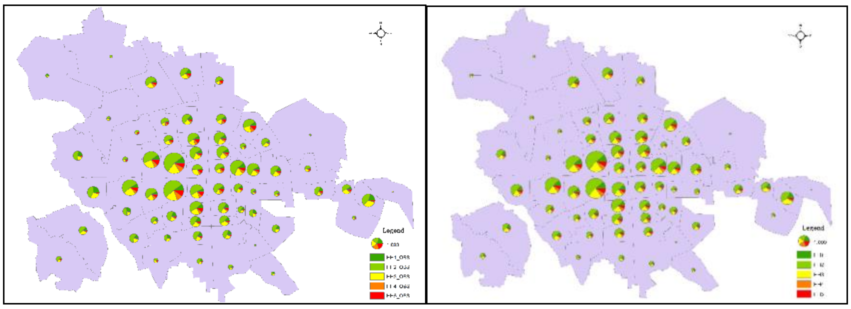

Figure 5. Comparison and Analysis of Calibration Results and Observed Values

From the comparison between the model's forecast results and observed values of each zone in the diagram it can be seen that the family structure proportions observed are basically in line with the forecast values, indicating the relatively favorable current condition restoration result of the model. Therefore, the model is useful.

3.2 Leasing Calculation Model

The leasing calculation model is mainly based on the distribution of the WTP of the residents as estimated by a demand model. Combining the house price distributions, the model is used to calibrate the relationship between WTP and house leasing.

When the Hedonic model is used to calibrate, the specific calculation formula is as follows:

$$\mathrm{Ln}(\mathrm{Price_i}) = \mathrm{Asc} + \alpha \times \mathrm{B_{hvi}}$$

According to the sample distribution of the investigated data, 71 transportation zones with relatively high reliability are selected to conduct the parameter regression calibration. The specific calibration result is shown as follows:

$$\mathrm{Ln}(\mathrm{Price}_i) = 7.397 + 0.791 \times \mathrm{B}_{hvi}$$

R^2 is 0.68, indicating the relatively good fitness of the model.

The house prices in various transportation zones in Beijing in the base year are calculated according to the formula. Compared with the house prices of regular residences in each area, the result of investigations and summarizations are shown in Figure 6.

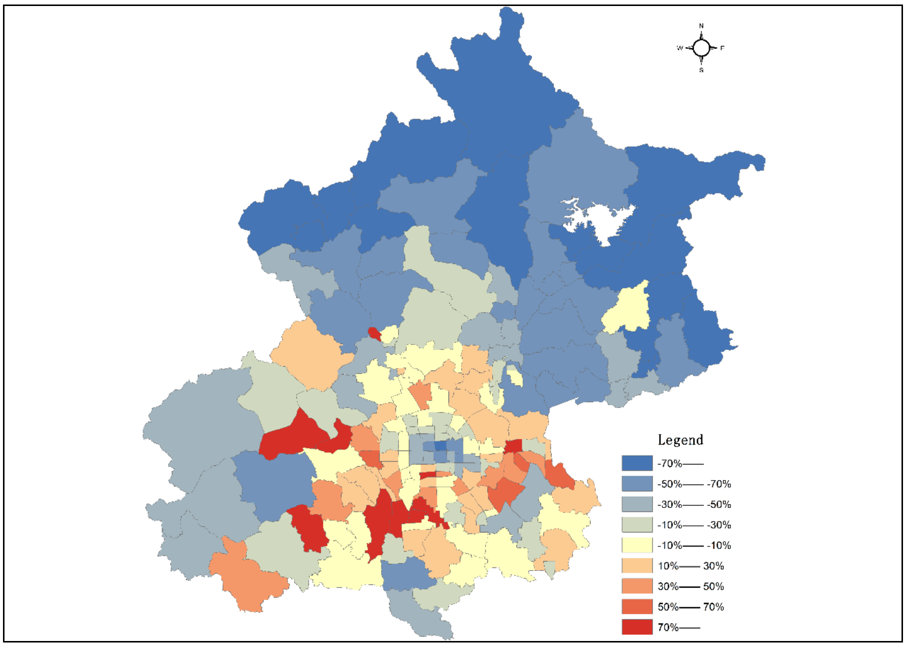

Figure 6. Differences between model data and survey data of house prices

From Figure 6 it can be seen that the distribution trend of house prices forecast by using the model is relatively favorable and presents an obvious center-outward spread, being higher in the north and lower in the south. The result of the comparison between forecast value and observed value indicates that the model forecast in the central city is slightly lower than the observed value. The forecast value of outward regions is slightly higher than the observed value. The accuracy of the overall forecast is relatively acceptable and thus the model is applicable.

3.3 Land Price Model

The land price model mainly aims to provide the land cost of real estate development for the development model and reflects the relationship between the land price and its influencing factors.

1. Analysis on Land Price Distribution in the Base Year

The transaction data and knock down prices of 407 residences from 2002 to 2010 are equivalently converted to 2005 values to obtain the house prices in each area in 2005. See Figure 7:

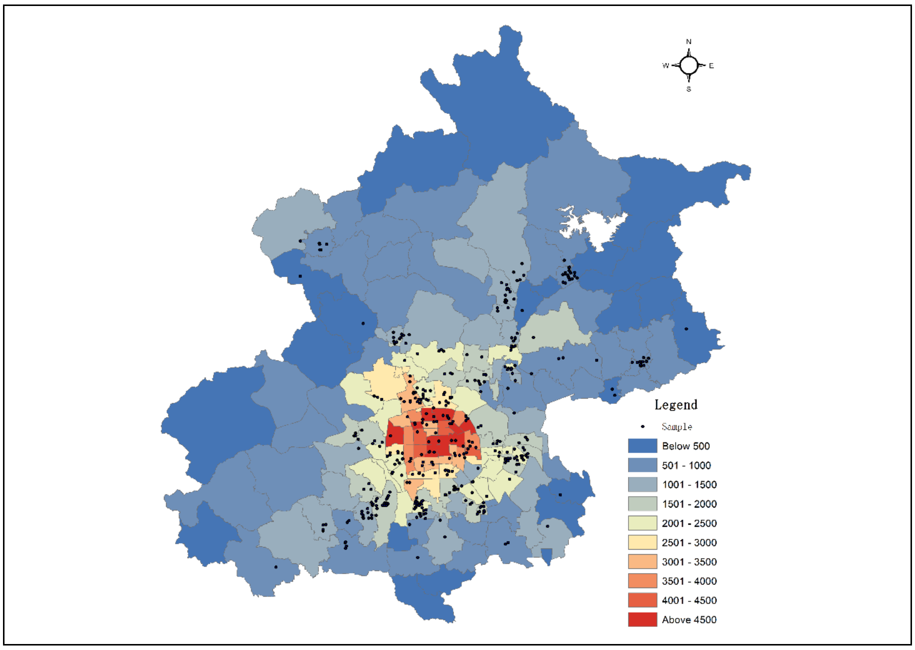

Figure 7. Distribution of relevant land prices of residences in Beijing in 2005

2. Selection of Independent Variables

After investigation and survey, it is known that the land price is mainly influenced by factors such as location, humanistic and social environments. The influencing factors are finally selected after analyzing the correlation of variables as well as land price correlation in the base year as presented in Table 3.

Table 2. Independent variables in the land price related factor analysis model

Independent Variable	Definition	Unit
PriDist	Nearest distance from the centroid of the transportation zone to any of the top-50 primary schools in Beijing	Km
ParkDist	Nearest distance from the centroid of the transportation zone to any of the 53 city parks registered in Beijing	Km
Acc	The location accessibility of the transportation zone can be expressed by the distance from the location to the employment area in terms of convenience.	——

3. Model Calibration

The Hedonic model is used to conduct model calibration of the land price and relevant influencing factors. The result of calibration is shown in the following equation.

$$\mathrm{Ln}(\mathrm{Land}_{price}) = 2.207 - 0.021 \times \mathrm{Pri}_{dist} - 0.007 \times \mathrm{Park}_{dist} + 0.535 \times \mathrm{Acc}$$

R^2 is 0.738, indicating the relatively good fitness of the model.

The results of model calibration are compared with the observed values as demonstrated in Figure 8.

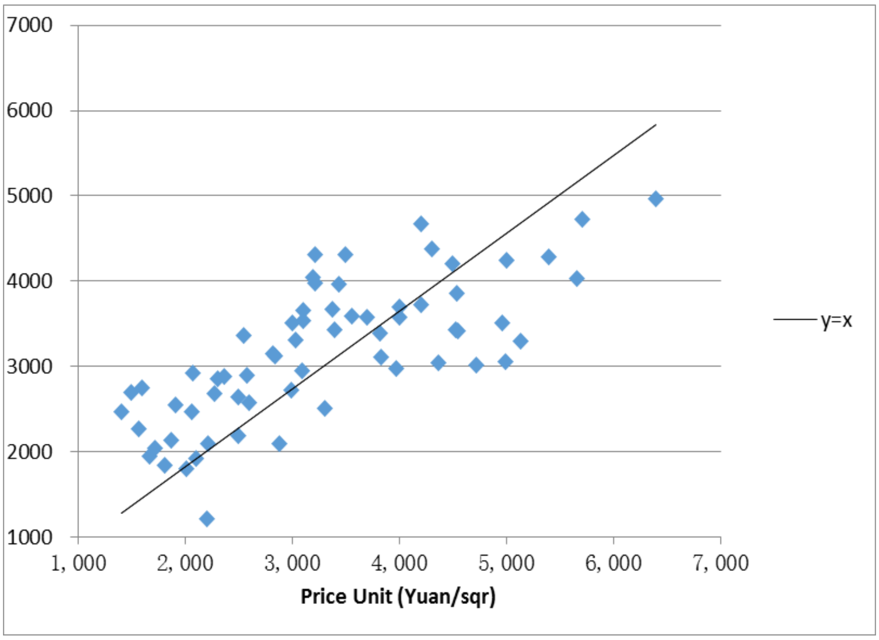

Figure 8. Comparison between estimated data and survey data

Figure 8 indicates that the estimated values produced from the model and the real values are quite similar. It should be noted that minor differences still exist in the forecast of individual values.

3.4 Real Estate Development Model

The establishment of a development model mainly simulates the development behaviors of the real estate market. It is well known that developers tend to select pieces of land available for development with the highest profit potential. A mathematical formula maximizing developers' profits can be expressed as below:

$$\mathrm{Max}\,(\mathrm{Price} - \mathrm{Land}_{cost} - \mathrm{Con}_{cost})$$

Where, Price represents the sales price of the house;

Land_{cost} represents the land purchase cost;

Con_{cost} represents the house construction cost.

In the model, the independent variable of land purchase cost is obtained from the land price model. The house construction cost in the base year is temporarily set as 800 RMB/m^2.

Under the precondition that the total development volume of the development model is already known (obtained from the exogenous total residence demand scale of the model), the development scale of each transportation zone can be calculated by using the development profit model that is composed of house price, land price and construction cost. The specific mathematical formula can be represented as follows:

$$S_i = H \times P_i = H \times \frac{exp(\pi_i)}{\sum_I \exp(\pi_i)}$$

The utility equation is represented as:

$$\pi_i = \alpha \times (r_i - land_{price_i} - \mathrm{Con}_{cost_i}) + \delta_i$$

BIOGEME is used to calibrate the development model. The calibration result of the equation is as follows:

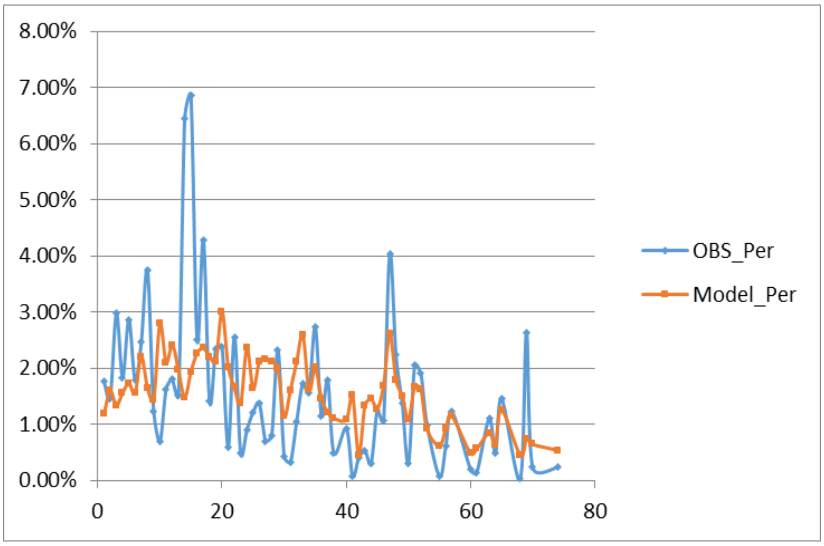

Figure 9. Comparison between predicted data and observed data

Figure 9 indicates that the overall developments of the two curves are relatively matched. In addition, the errors in most transportation zones are relatively small, which proves the validity of the parameters used in the development model.

3.5 Accessibility Calculation Model

In order to reflect the influence of transportation systems on land use in a more objective way, an employment accessibility index of the application area is used to mirror the impact of the real estate development behaviours on residential location selection. Meanwhile, the location accessibility is also used as the basis for the establishment of land price in order to comprehensively reveal the influence of transportation systems on the land use.

The comprehensive transportation cost calculated by using a BMI model is used in this accessibility variable. Combining the trip mode structure of different family groups and the regional distribution of jobs, the calculation is carried out. The calculation formula is as follows:

$$Acc_{hi} = \sum_{j \in J} \ln\left(\frac{Emp_j}{\sum_{k \in K} GC_{kij} \times Per_{kh}}\right)$$

Where, Acc_{hi} represents the employment transportation accessibility of family *h* in Zone *i*;

Emp_j refers to the jobs in Zone *j*;

GC_{kij} represents the generalized trip cost from Zone *i* to Zone *j* under the trip mode *k*;

Per_{kh} refers to the ratio of trip mode *k* related to family *h*.

4. APPLICATION

In this section, the influence of decentralization of the top hospitals on the residential distribution and land development changes is taken as an example for model application.

Currently, there are, in total, 44 top hospitals in Beijing that are representative of the best medical level in Beijing, even in China. All the top hospitals are located in the center of Beijing. The majority of the hospitals are located within the fourth ring road as indicated in Figure 10.

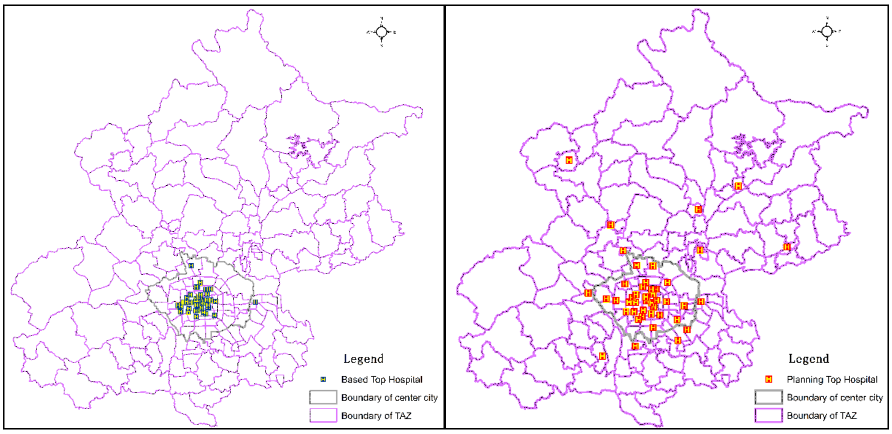

Figure 10. Current distribution and planned decentralization of top hospitals

In light of the fact that there exists excessive centralization of top quality medical resources in Beijing, the Beijing Municipal government proposes the idea of decentralization of these resources in its integration planning in hopes that each new town has at least one top quality hospital. In this, planning considerations of the obvious influence of medical resources on residential location selection, as well as on the relocation of the population from the central part of Beijing, are made.

In order to test the influence of this planning scheme on the residence supply and population distribution, the BLUTI model is used to test and compare the practices of maintaining the current locations of the top hospitals that are unchanged in the planning year and implemented in the decentralization planning. The test results of residential real estate development and household distribution are shown in Figure 11 and Figure 12, respectively.

From Figure 11 and Figure 12, it can be seen that the decentralization of top hospitals as planned has a certain promotional effect on the residential development and relocation of the population outward. This is beneficial to the migration of the population in central Beijing. However, the effect of population migration brought by decentralization of top hospitals alone is not very evident. It is recommended to adopt other policies as well.

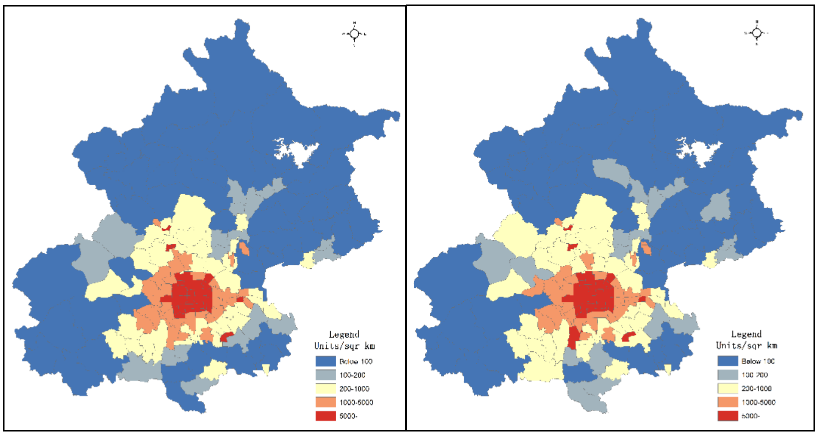

Figure 11. Comparison of based and planned residence supply density

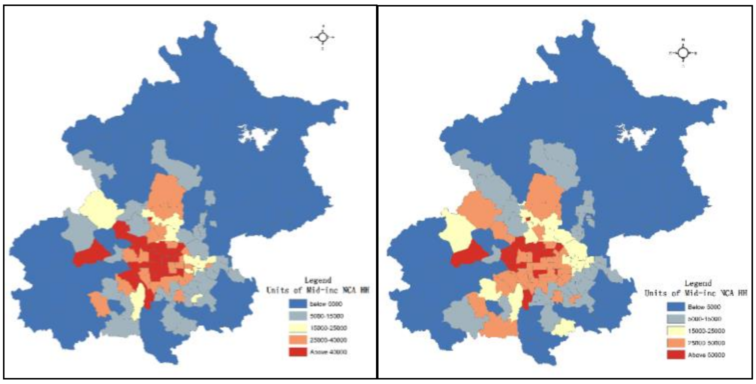

Figure 12. Comparison of based and planned Mid-Income No Car Available Household Distribution

5. CONCLUSION

The main achievement of this research is, for the first time, the completion of the calibration of a Beijing transportation and land use integrated model based on the traditional transportation model of Beijing and land use data. Some applications of the model, such as an exploration of the effect of top hospital decentralization, are also made.

Furthermore, the calibrated model has provided a set of relatively feasible and effective quantified analysis tools for the evaluation of the master planning of Beijing in future development. In addition, the model can help conduct scheme testing processes that are related to urban land use planning and transportation system planning, as well as related policy analysis and strategy research.

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International review for spatial planning and sustainable development, Vol.5 No.1 (2017), 86-103
ISSN: 2187-3666 (online)
DOI: http://dx.doi.org/10.14246/irspsd.5.1_86

Analysis of the population displacement phenomenon under tourism economy development in Chinese historical areas:

Based on Social Exchange Theory

Ruoxi Zhang[1*], Yunyi Zhang[2], Xuting Liu[3], Qiuyi Yin[4] and Lvxia Yang[5]
1 School of Architecture and Civil Engineering, Xiamen University
2 Centre for Advanced Spatial Analysis, The Bartlett, University College London
3 School of Architecture and Civil Engineering, Xiamen University
4 School of Architecture and Urban Planning, Nanjing University
5 School of Urban Design, Wuhan University
** Corresponding Author, Email: zhangruoxi@xmu.edu.cn*

Received: March 19, 2016; Accepted: June 30, 2016

Key words: Population displacement, Chinese historical areas, Social exchange theory, Kulangsu

Abstract: In recent years, tourism's commercial exploitation of China's historical areas has been in full swing. However, the status quo of those historical sites is increasingly worrying due to their over-commercialization, the dissimilation of original lifestyles and, especially, the phenomenon of population displacement, with historical residents moving out and the non-native population flooding in, which directly gives rise to the loss of traditional culture. As per our investigation of Kulangsu, concerning its current population and culture situations, this paper aims to dig out the root cause of the population displacement, grasp the law and features of this phenomenon, analyze the significance and impacts it brings about and put forward optimization proposals for the sustainable development of Kulangsu Island.

1. INTRODUCTION

1.1 Research background

In recent years, the rise of commercial tourism in historical areas has vitalized the previously declining blocks with a new look in China. However, the development of historical and cultural blocks is worrying due to its deep commercial atmosphere and scarcity of primitive ecological life (Niu & Wang, 2015). Nowadays in China, there are a number of historical areas losing their original appearance of cultural connotations in many cities because of the emigration of existing residents, the immigration of new residents and migrant workers (Wu, 2008), and the conversion from residential to commercial functions (Xu, 2012). These phenomena also directly bring about the degradation of both the cultural value of historical blocks and their original residential functions, changes in social structure and the disappearance of the characteristics of traditional community life, thus triggering various potential social conflicts (Wu, 2008).

Our investigation focuses on the causes and characteristics of the population displacement phenomenon, which stems from tourism's exploitation of Chinese historical blocks, to explore potential solutions, to a certain degree, to keep the population of historical residents and traditional lifestyles, and to preserve the authenticity of life in historical areas. In regard to the research on population displacement, academia in China has hitherto placed emphasis on discussing urban gentrification under the backdrop of globalization, analyzing the phenomena of government-driven capital reinvestment and the immigration of the middle class in those old towns, and so forth (Chen & He, 2012; He, 2007, 2010; Zhu, Zhou, & Jin, 2004). Highlighting the phenomenon of population displacement induced by tourism, Mo (2013) analyzed the case of Old Town of Lijiang where it occurred that the indigenous peasants emigrated for adaption while the external industrial developers immigrated for commercial opportunities arising out of over-commercialization. However, the author did not dissect the causes of the social problems.

This paper introduces the case of Kulangsu in Xiamen Province, China, which is an island with an area of 1.88km^2. Kulangsu was originally an international settlement in the early 1900s and gradually became a unique international community due to the constant multicultural collision. Nowadays, there are still a considerable number of buildings from every era remaining. In recent years, Kulangsu has been found to embrace enormous economic and tourist values and thus has been exploited endlessly. As a tourism destination, the highest average number of visitors per day has been recorded as 60,000. This has leaded to tremendous shifts in its original residential social structure and the emergence of population displacement. Kulangsu can be regarded as a great introduction to Chinese historical areas being or having being over-exploited for tourism and commerce, that is, it is a historical area in miniature, which is teeming with multiple social problems after excessive tourism and commercial exploitation.

This paper will base its investigation on Social Exchange Theory and the chemical displacement reaction to figure out the inducements, processes and results of the population displacement in Kulangsu, analyze its law, characteristics, influence and significance, and put forward feasible suggestions to achieve sustainable development in Kulangsu.

1.2 Theoretical basis

Social Exchange Theory is a social theory which emerged and prevailed in the 1960s, advocating that all human activities related to social relations should be oriented by reward and remuneration based on the assumption of selfish humanity. Mainly there are two schools of Social Exchange Theory:

Table 1. Brief analysis of the two schools of Social Exchange Theory

Modern Social Exchange Theory	Theoretical features
Behaviorism Exchange Theory by Homans (1958)	Any human's activity can be explained as rational exchange behavior based on interest
	Possibility for the occurrence of behavior=value× rate
Structural Exchange Theory by Blau (1964)	Social exchange is caused by social attraction while social attraction is caused by economic motivation
	Basically all human communication modes are a process of attraction, competition, division and integration

There has been relevant research on urban social relationship analysis applying the two theories from Table 1, above, in Chinese academia. Zhou (2012) investigated the relationship between residents' individual benefits and their perceptions on tourism impacts based on Social Exchange Theory. Yang (2008) discussed the issue of community participation and the relationship between tourism income and cost yielded from the process of tourism development. Zhang (2010) applied Blau's Structural Exchange Theory (1964) to analyzing the problems of integration of rural migrant workers and urban society from the perspective of labor sources, social rewards and so on.

Both theories can be used to explain the reasons for population displacement in historical areas, especially in Kulangsu. Both primitive residents' emigration and migrant population immigration are rational behaviors guided by interest with a trend of attraction, competition and diversion shown during their collision. Thus, we are going to study and analyze the essential reasons for, trend and optimization of population displacement with Social Exchange Theory as the theoretical basis.

1.3 Definition of the concept

1.3.1 Population displacement

The population displacement studied in this paper refers to a phenomenon regarding the emigration of historical residents who have lived for over ten years, as well as the immigration of an external population who have lived for one year to ten years in a particular historical area.

In order to study the root reasons for population displacement as well as its development and optimization of the status quo, "displacement reaction", which in chemistry is used as a carrier with Social Exchange Theory, is going to be used as an analogy and for building the equation for population displacement (see *Figure 1.* Establishment of the equation for "population displacement") by the principles of displacement reaction and the deep principles of this reaction.

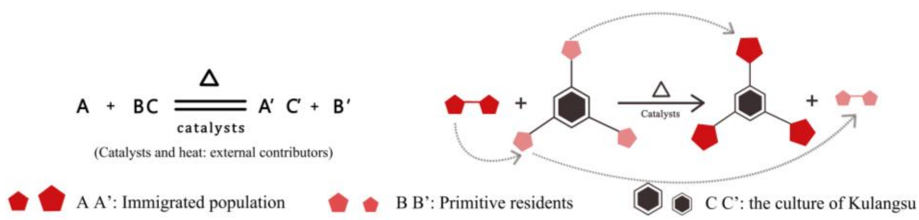


Figure 1. Establishment of the equation for "population displacement"

Under certain catalysis, as well as displacement reaction in different stages, the alienated immigrant population, historical residents, as well as the culture of Kulangsu are reproduced and referred to as A'B' and C', within which B' is isolated while A' and C' are combined together. Therefore, occurrence conditions as well as results of population displacement are problems to be discussed in this paper.

Table 2. Explanation for main concept definition of population displacement

A (immigrant population)	Immigrant population who have lived here for more than one year but below ten years due to vigorous development of commercial tourism in Kulangsu

B (historical residents)	Residents who have lived on the island for more ten years
C (Kulangsu culture)	Multi-culture formed by history and transition in Kulangsu

1.3.2 Displacement activity

The conditions for a chemical displacement reaction is expressed as: activity of metal A is stronger than B, and then it can replace B. This principle is also adaptable to population displacement following a similar reaction principle. According to Homan's Social Exchange Theory, all human social interactive behaviors are exchanges based on interest. Therefore, we can contribute the reaction activities of A and B to the direct interest correlation of Kulangsu's overall development, including culture and commerce.

Table 3. Explanation for parameter definition of the population displacement reaction

Conditions for chemical displacement reactions	Chemical reaction activity A > B
Preconditions for population displacement reactions	Reaction activity of immigrant population A's social activity is stronger than the reaction activity of historical resident B's social activity
Displacement activity	Comprehensive index of subjective initiative and objective effect in protecting history and culture and developing commercial tourism in Kulangsu
Determine factors of displacement activity	Direct interest correlation with Kulangsu's overall development regarding culture and commerce

1.4 Research framework and purposes

The paper aims to firstly explore the stimuli for the population displacement phenomenon in Kulangsu, then, via field investigation and questionnaire interviews, we are able to select variables on each aspect of Kulangsu to master the law and characteristics of the displacement phenomenon, and figure out the effects and significance being exerted on the local situations. Eventually, several suggestions can be proposed for the sustainable development of Kulangsu under the wider background of tourism commercialization.

1.5 Study area

Kulangsu is a typical example of an historical area in China. Due to multiple factors, most historical residents of the island have moved out to other places while many immigrants have come for commercial activities with an increasing and uncontrolled growth trend. Kulangsu has become lonelier and lonelier with massive losses of historical residents. Population displacement has become an internal injury of Kulangsu.

In a bid to analyze the phenomenon of "population displacement" in Kulangsu, this research focuses on the whole island, situated to the southwest of Xiamen Island. Kulangsu mainly consists of two communities as well as typical historical blocks: Longtou and Neicuoao, both of which are partially selected as the samples and investigation areas for the research:

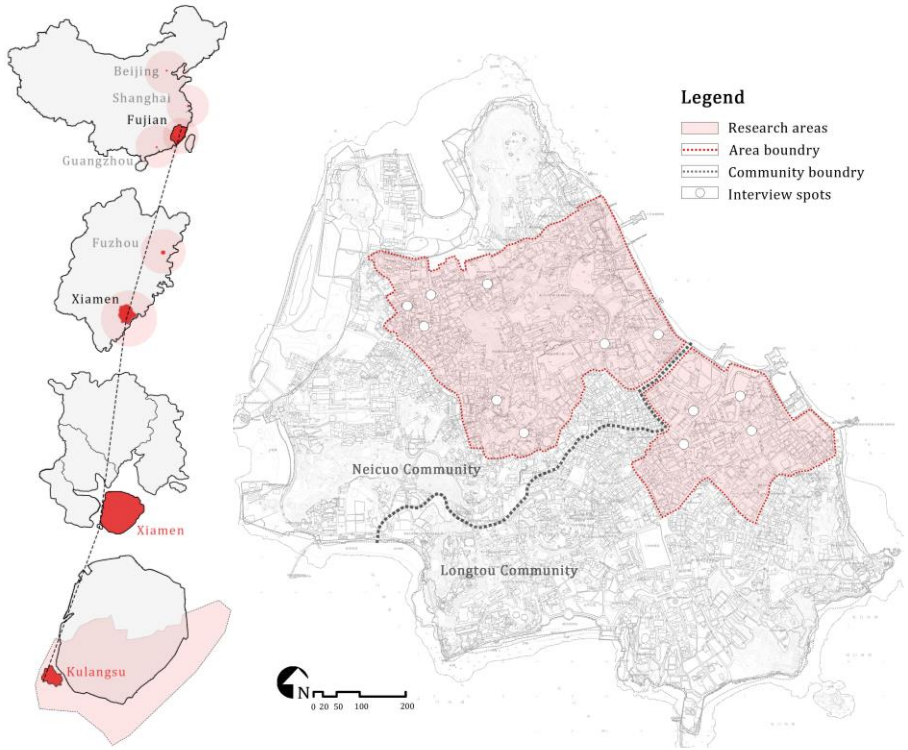


Figure 2. Location map of Kulangsu and illustrations for research areas and interview spots

2. ANALYSIS AND FINDINGS

2.1 The emergence and cause of population displacement

Kulangsu was once a wild oasis without human habitation, until the earliest human settlement appeared in the 1270s. With groups of people immigrating for initial construction, there were incremental resident populations living on the island.

Due to the country's loss during the Opium Wars, Kulangsu was partitioned and occupied by 13 other countries, which finally made the island an international settlement as well as one of the most intensive geographical units as a cultural melting pot in the world, with the population reaching 5000 in the early 1900s and peaking at 40,000 in 1941.

When the administrative area was determined in 1949, Kulangsu underwent a crucial period of development transition from a mixed residential community gradually to a tourism destination, and was listed as a national key scenic spot in 1988. Responding to the new plan for Kulangsu, the government of Amoy City implemented the policy of "population reduction" in 1993, by issuing a Contemporary Stipulation for Population Management in an urban area, this put more emphasis on the tourism development with little focus on other urban functions. The population gradually decreased to 20,000 around 2000 along with the removal of several factories and companies.

Having benefited a lot from tourism and commercial development, the island was oriented to continue strengthening the attributes of scenery and traveling while weakening its original attributes of residence and community. Accordingly, Administrative Measures for Kulangsu, Xiamen were issued. Historical residents' lives were tremendously affected due to the emerging dual management of community and scenic spots, triggering a migration tide of residents for the second time. Meanwhile, however, people outside the island flew into Kulangsu constantly, induced by tourism and commercial development, who attempted to make maximum economic benefits by doing business and making a living on the island. In 2010, there were about 14,000 residents on Kulangsu Island, of which 6,000 were immigrant people and merely 8,000 were the historical residents, still facing a fast population loss rate.

Till now, Kulangsu has become better-known around the world just as a gorgeous and romantic tourist destination, while its original image as a mixed and multi-cultural residential community has gradually been destroyed and buried, which mirrors dramatically the unbalanced development between commercial tourism and protection of inheritance and traditional culture.

Therefore, according to the migration flows in the history of Kulangsu, "population displacement" can contribute to the "push-pull effect", which is analyzed in *Table 4* (i.e. the catalyst and heating conditions).

Table 4. Analysis on the contributing factors to population displacement

Contributions of "population displacement"	**Essence**	**Effects**
Propulsive force	Push out historical residents by government's mandatory development policies	Two migration tides: 1) "Population reduction" policy by Xiamen government in 1993; 2) Management Methods for Scenic Spots issued in 2005, resulting in a dual management by community and scenic spot managers. Side effects: Vicious circle of "population reduction--removal of companies" and "removal of schools and hospitals---population reduction".
Tensile force	Attraction to massive external labors because of the interest from tourism commercialization	Constant emigration of historical residents and immigration of external laborers attracted by tourism commercialization. Many impacts on primitive folk and culture have been made in Kulangsu while seeking development and interest.

2.2 The status quo and influence

2.2.1 The status of population

Basic demographic information is collected via official data and questionnaires, being statistically analyzed and shown in Figure 3.

It can be concluded from the chart that the immigrant population has a younger age structure than the historical/primitive with 68% of people under 30. As far as we know, most immigrant people (63%) are merchants from other places within Fujian while quite a few are from other provinces, and still 32% are local. Those immigrant people universally lack enough knowledge about Kulangsu's traditional culture and history due to their relatively short time living on the island (78% have lived here for only 1 to 5 years), which constitutes a great hindrance to community and cultural protection. For the historical residents, however, 82% of them have been living here since childhood and are over 10 years, embracing their own religious belief and sense of belonging to the island. Thus most of them (70%), especially the seniors, are reluctant to move out since they think the environment in Kulangsu is still good for living, while younger people are willing to leave for better development.

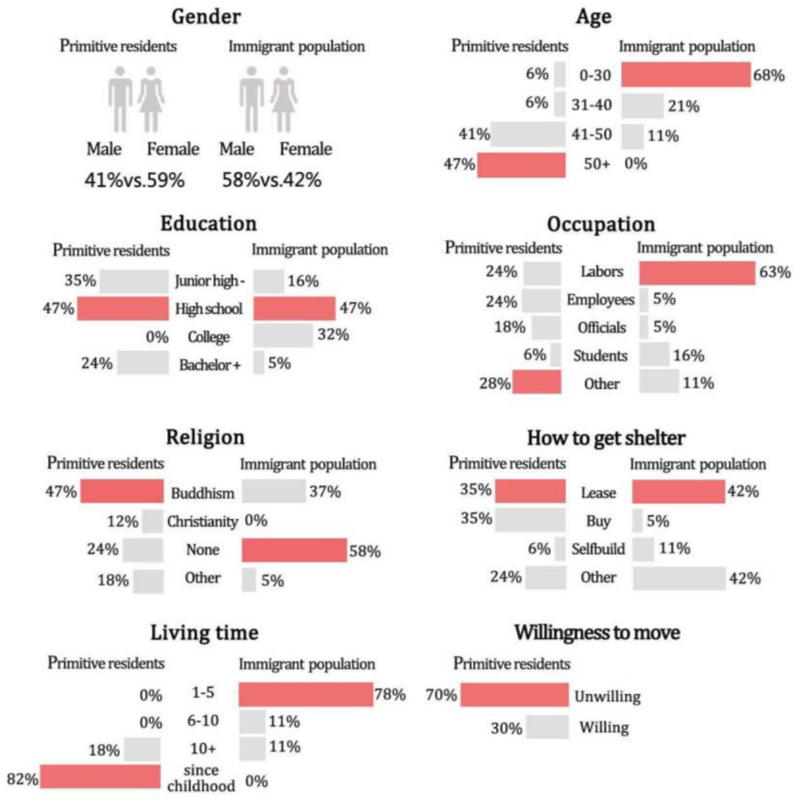


Figure 3. Statistical chart of basic demographic information in Kulangsu

2.2.2 Life and culture

For the investigations concerning life and culture, different opinions are given by historical residents and immigrant people addressing life and activity conditions in Kulangsu.

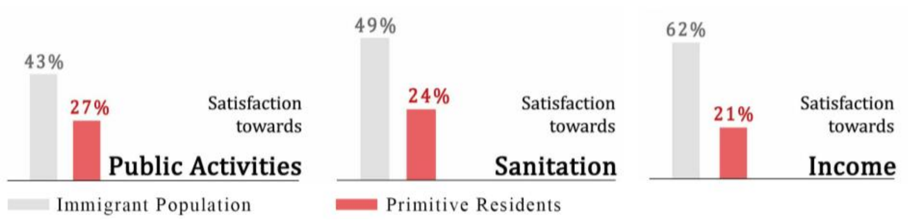


Figure 4. Difference of satisfaction towards public activities, sanitation and income

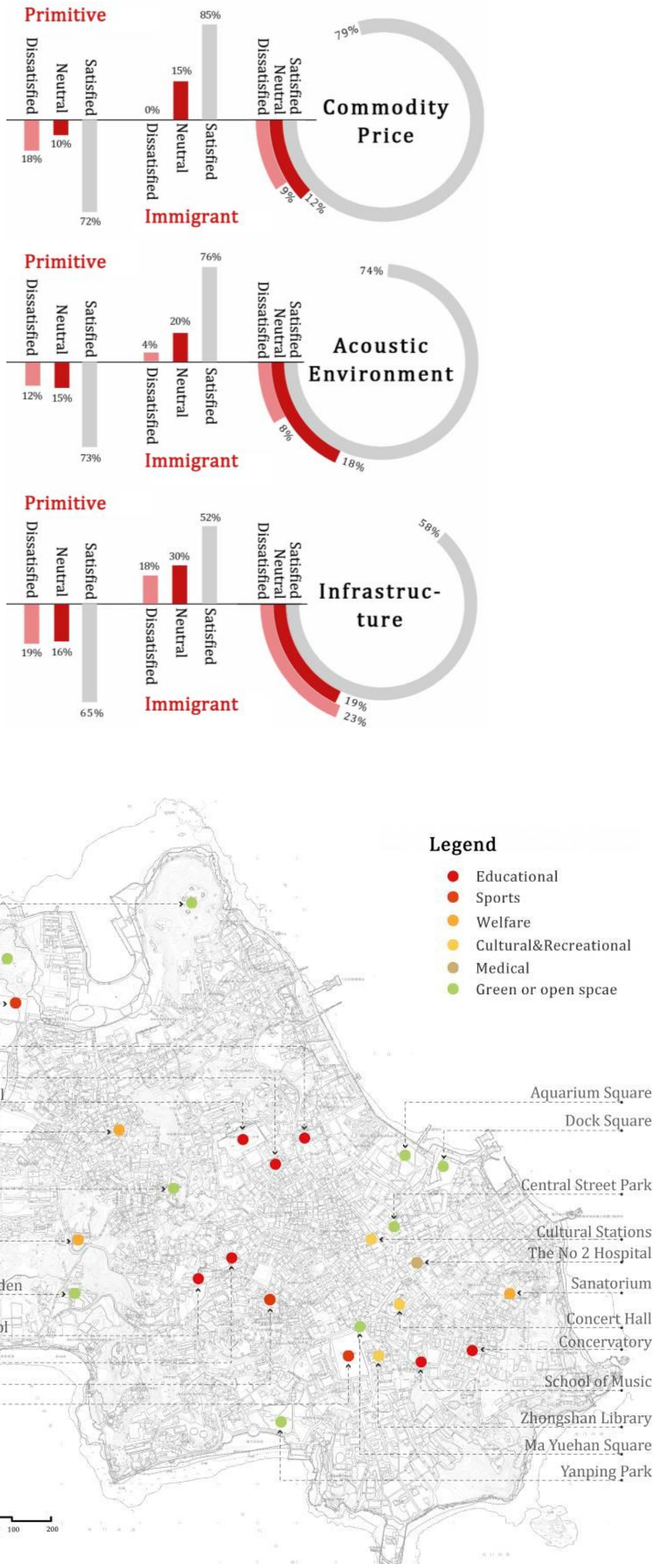


Figure 5. Satisfaction consensus of commodity price, acoustic environment and infrastructure, and distribution of current infrastructure

1) Primitive residents are universally dissatisfied with the health and environment, public activities and income level, while immigrant people are positive about these aspects.

As to public activities, immigrated residents seldom participate and they think improvement has been made for public activity facilities only with scenic spots and many parks in Kulangsu. For the primitive, although the government has built facilities for public activities, atmosphere for residents' participation in public activities no longer existed with a compression of activity space, since the immigrant population focus on commercial benefits without knowing the value of public activities.

When comes to health and environment, immigrated residents pay more attention to the beautiful natural scenery in Kulangsu without much more observation on public health and environment for their short residence here, while most primitive residents think that health conditions have become worse obviously with the development of commercial tourism as well as immigration of external people.

Additionally, the development of tourism and commerce has brought incremental income to immigrant people, who directly participate in these commercial activities. However, the majority of the primitive usually benefit little from the tourism.

2) Both historical residents and immigrant residents are dissatisfied with problems in Kulangsu like the shortage of infrastructure, noisy environment, rising prices, as well as complex staff.

According to the investigation, we find that prices for food and daily necessities have been raised by merchants, especially by those who run a dining business, and all residents' cost of living has been raised. With the development of commercial tourism, Kulangsu is no longer quiet due to the deep commercial atmosphere from merchants and visitors. Furthermore, the scarcity of infrastructure has become one of the main reasons for loss of the historical residents.

3) The two kinds of residents have no special inclination towards family relationships and neighborhood relationships which are varying from people to people.

Family relations is a relatively private problem which differs between people without any direct relation to population displacement in Kulangsu as found in the interview results.

On the whole, residents in Kulangsu have low satisfaction about life conditions here and according to Social Exchange Theory, it is mainly due to the pursuit for interest maximization. The deep commercial atmosphere of tourism in Kulangsu results in more pursuit for economic benefits from tourism development, but less attention on intangible values about life conditions by local residents, especially by immigrant people.

2.2.3 Architectural culture

Buildings in Kulangsu have diversified functions with many old buildings being transformed to stores for business. Both the historical and immigrant people permit the illegal construction and transformation of old buildings into stores or hotels.

We can see from *Figure* 6 that many buildings have retained their living function with various matching public service facilities in the Neicuoao community, with an overall retaining of basic form and structure in the living community; while in Longtou community, many buildings have been transformed to stores as hot areas for tourism and commerce.

As per building quality, buildings can be categorized into four classes. First-class includes public buildings as well as newly built houses with good quality; the second and third-class are houses for common people and partial stores; also there exist some slum-dwellers, illegal constructions as well as old dangerous decrepit houses with poor quality.

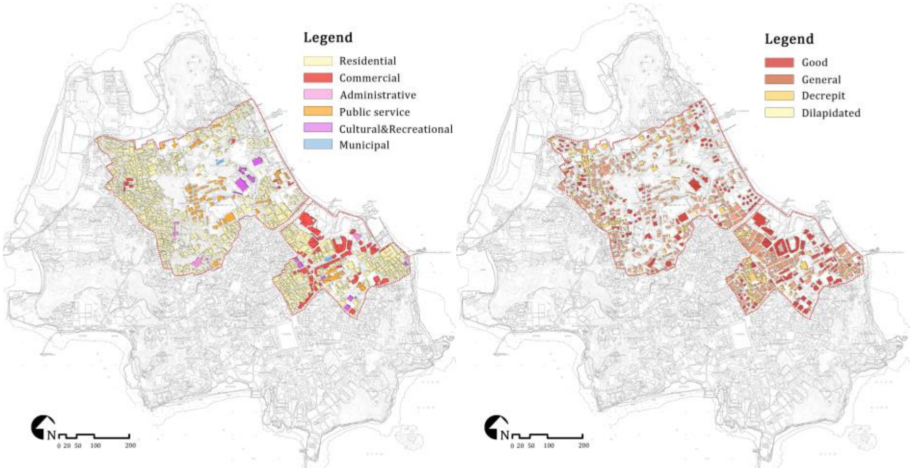


Figure 6. Current building function and quality in Kulangsu

2.2.4 Religious culture

The figure below shows us the situation of importance of traditional festivals to the historical residents, B.

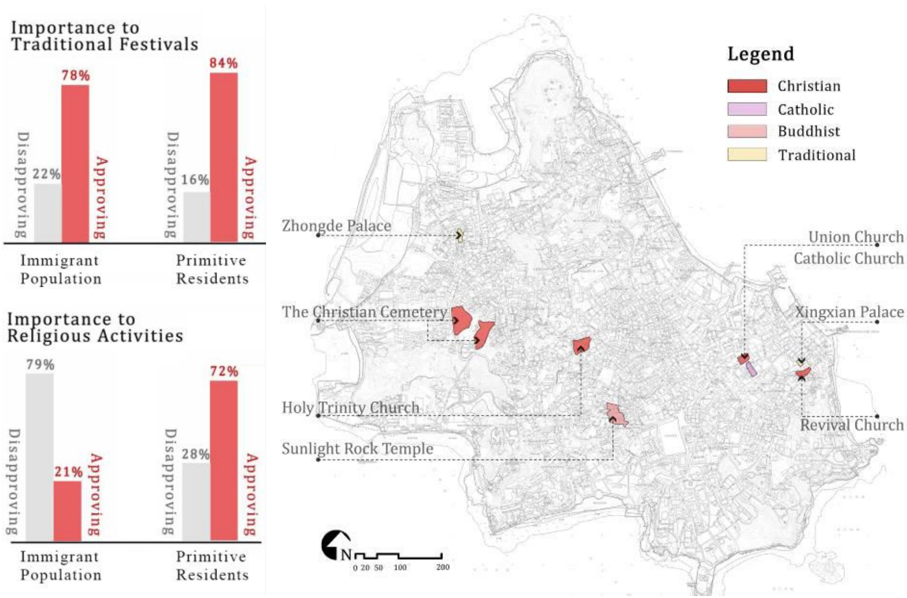


Figure 7. Importance to traditional festivals and religious activities and distribution of current religious and cultural facilities

2.2.5 Culture with characteristics

1） The family musical culture has become weak with low popularity of music and shortage of musical aesthetics.

Historical residents expressed their knowledge about Kulangsu's history as a musical island, but they said the musical culture has been disappearing with the gradual removal of rich families. The remaining ones know little about musical theory due to their limited education and life conditions. Although some of them still keep musical instruments like pianos, they were played by young people before who are no longer living on the island.

But for migrant workers, they have less chance to make contact with music due to their low education level, busy work, and big life pressures, so most young migrant people did not know the characteristic culture of Kulangsu as a musical island when they first came. Therefore, characteristic musical culture is just a propaganda slogan without any practical scene of beautiful music around the island under the gradually deepening tourist commercialization. The musical island has become legend.

2） The Hokkien and Mandarin languages have become a fifty-fifty split, with Mandarin becoming more popular.

Most interviewees showed that Mandarin has become more and more common and popular. Communicating in Mandarin is more convenient for visitors since they come from different places under the background of developing tourist commercialization in Kulangsu, although the historical residents insist on speaking Hokkien. Hokkien, as the official language before, has been impacted by Mandarin for the pursuing of economic benefits under the tourism tide. Some historical residents of middle and old age even said their children and grandchildren cannot speak Hokkien anymore.

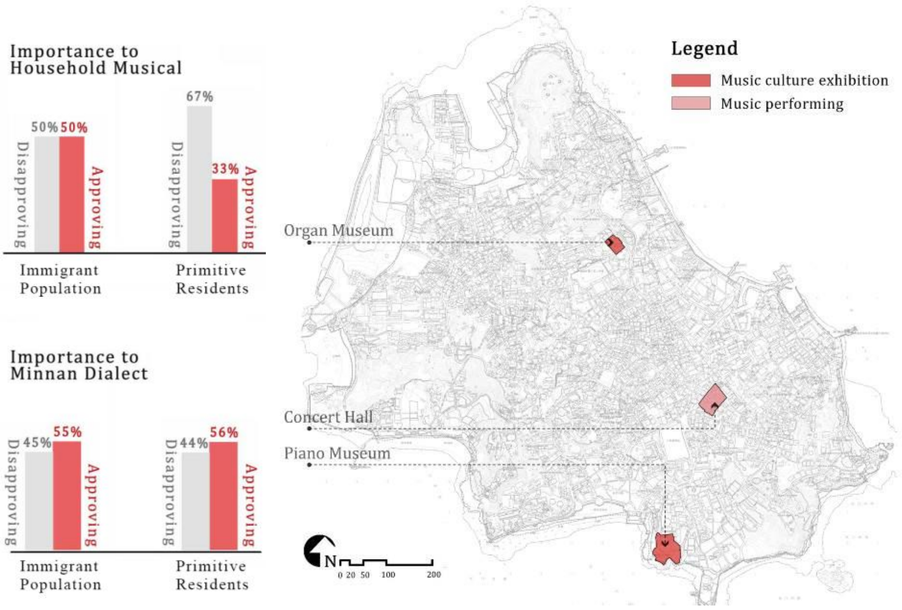


Figure 8. Identification of characteristic culture and distribution of current musical and cultural facilities

In summary, it can be found based on the investigation that neither historical residents nor immigrant residents are thoroughly satisfied with life and culture, especially the historical residents who are relatively more dissatisfied with the living environment, income level, social relations, etc. As to architectural culture, both historical residents and immigrant residents think the same, that buildings have not been well protected. In addition, in terms of religion and language, as well as musical culture, both historical residents and immigrant residents agree to value and protect them.

3. FEATURES AND RULES OF POPULATION DISPLACEMENT

3.1 Summary for displacement stage

According to Social Exchange Theory by Blau (1964), the process of human communication modes mainly includes attraction, competition, division and integration, which also fits for population displacement. However, based on basic investigation, population displacement in Kulangsu may be secondary to division after diversification according to the current trend. The major four development stages for population displacement in Kulangsu are shown in Table 5:

Table 5. Parameters of displacement reactions in each stage

Reaction stages	A	B	A activity	B activity	Comparison of activity	The overall activity
Attraction	↗	-	↗	-	A<B	↗
Competition	↗	↘	↗	↘	A>B	↗
Diversification	-	↘	↗	↘	A>>B	↘
Division	-	↘	-	↘	A>>B	↘

** A – Immigrant population, B – Historical/Primitive residents*

1）Attraction

In the beginning, some migrant workers came to Kulangsu under the government's vigorous promotion of tourism development. At that time, Kulangsu had a large demand for laborers since tourism development was in the primary stage and culture at that moment also remained in its primitive condition.

A (immigrant people): They had an increasingly stronger will to reform Kulangsu with higher activity. According to Social Exchange Theory, it is easy for migrant workers to get job opportunities and gain economic benefits from tourism commercialization directly since laborers are scarce during the initial stage of development.

B (historical/primitive residents): Compared to migrant workers, historical residents belong to laborers with higher cost, who are less likely to be hired by employers with less participation in commercial development without direct material benefits. B just keep a stand-by attitude towards such development with a low activity.

2）Competition

Cultural brands in Kulangsu have become gradually mature with the increase of benefits from commercial development; meanwhile A (immigrant people) have entered Kulangsu for benefits on a massive scale with constantly increasing activity. On the contrary, B (historical residents) began to leave Kulangsu because of the deteriorating environment, declining cultural atmosphere and rising prices impacted by commercial tourism development with a decreasing population. Most of those who have left are young and a strong labor force, so both subjective will and objective capabilities are decreasing for historical residents with lower activity. Thus A has been growing gradually stronger than B in terms of activity.

Then the displacement action occurs at this moment, during which both commercial development and traditional culture protection have been developed with an increase of overall activity since migrant workers are coexisting with historical residents.

3）Diversification

As a famous tourist attraction, Kulangsu has matured under operation. The government was forced to remove historical residents from deteriorating environments and rising prices due to the massive inflow of benefit pursuers. Thus, A’s activity reached a peak while B’s activity decreased regardless of quantity and quality. The displacement reaction has developed into an incandescent state.

Kulangsu overall is under huge change accompanying the displacement reaction. Due to the incompatible proportion between traditional culture protection and commercial development, many problems have resulted such as environmental deterioration and a deep commercial atmosphere with a declining development activity for Kulangsu on the whole, which is also the status quo of Kulangsu we are researching.

4）Division (forecasting stage)

The population displacement will finally reach a division stage if the conditions continue to deteriorate as per the current trend. That is, all of B are removed with zero activity left and complete division of traditional culture and commercial development. Without support of traditional culture, Kulangsu will become a commercial island completely, which is unlikely to receive sound and sustainable development as such a pure commercial scenic spot. A’s benefits are also contemporary since Kulangsu will be finally in decline with the overall decrease of development activity.

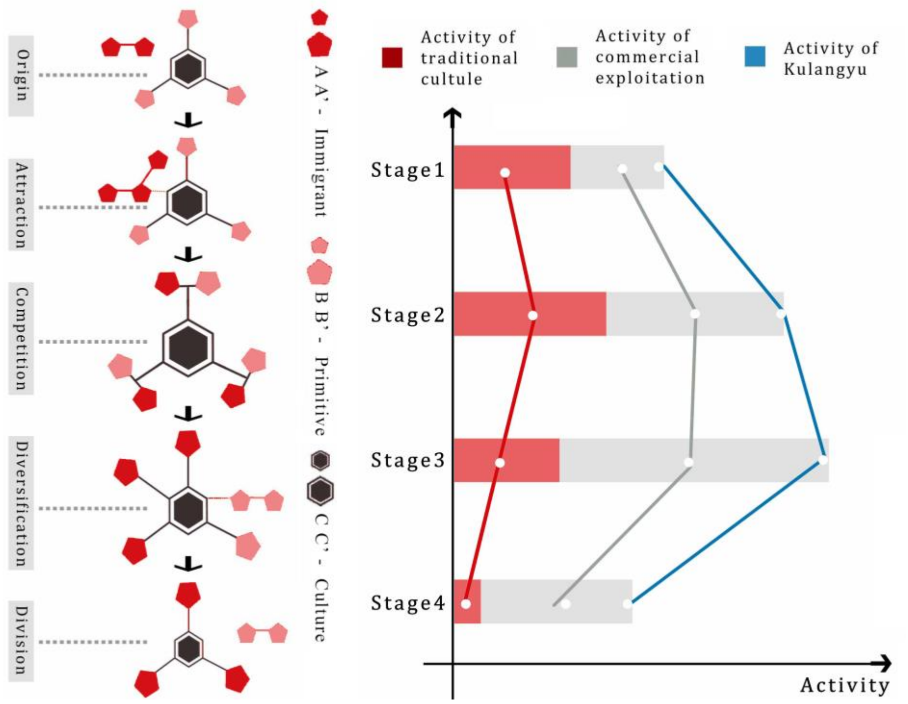


Figure 9. Summary of stages and law of population displacement in Kulangsu

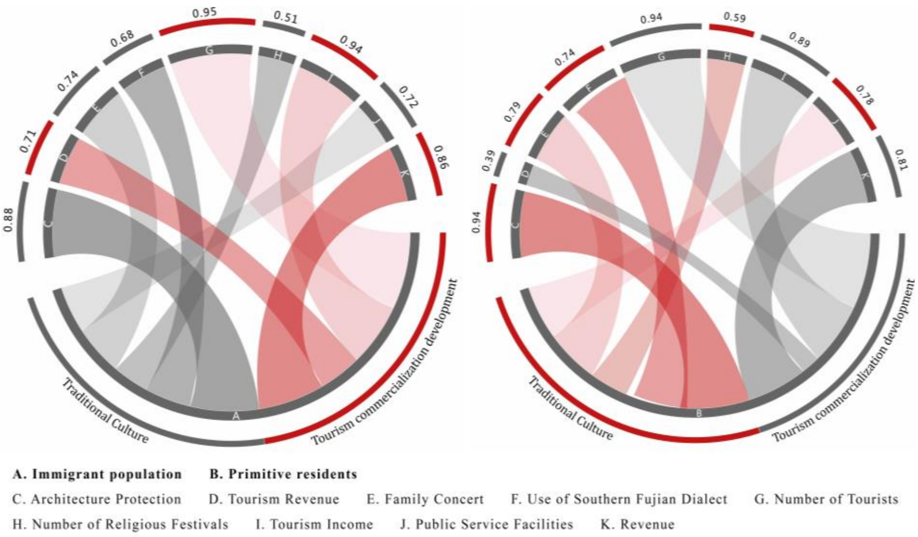
3.2 Analysis on correlation coefficients

To explore the correlation and relationships between traditional culture as well as commercial exploitation and the population of historical residents and the immigrants, we collect residents' demographic data and data concerning culture and commerce as variables over eight years (2006-2013) to perform an analysis of correlation coefficients. Since the variables are numerically far apart, data initialization should be done first.

Then, the correlation coefficient is calculated via the formula:

$$Correl(X,Y)=\frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}}$$

where *x*, in this case, is the population of historical and immigrant residents, while *y* represents the figure for each selected variable. The results are shown as follows:



	C	D	E	F	G	H	I	J	K
A (Immigrant)	-0.87	0.71	-0.73	-0.67	0.94	-0.50	0.94	-0.72	0.86
B (Historical/ Primitive)	0.93	-0.38	0.79	0.74	-0.90	0.59	-0.89	0.78	-0.80

Figure 10. Calculation results of correlation coefficients

According to the results, basically, the population alteration trend of historical residents has highly positive relationships with the variables relating to traditional culture, while it has highly negative relationships with economic and commercial variables. However, the figure for the immigrant people embraces thoroughly opposite relationships with those factors.

A (immigrant people) have always gained direct economic benefits during the irreversible process of tourism commercialization. They are attached to commercial benefits without connections to cultural protection in Kulangsu. On the contrary, B (historical residents) are attached to cultural protection without gaining any direct benefit from tourist commercialization.

Therefore, only if we connect A's and B's benefits with tourist and commercial development and historical cultural protection during the displacement reaction, so that balance can be reached for A and B's activity

(C), can an optimal result for A, B and C's sustainable development be achieved.

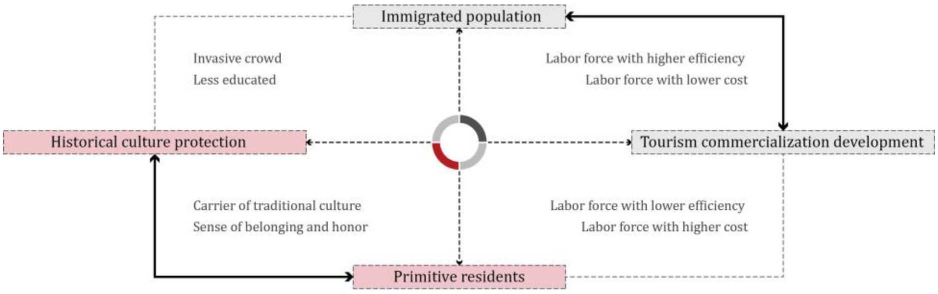


Figure 11. Illustrations of the current benefit correlations

4. SUGGESTIONS AND OPTIMIZATION

According to the theories above, suggestions are proposed in the following part to balance activity and implement benefit connections.

4.1 Prescriptive measures

Allowance: special allowance is abstracted from Kulangsu tourism taxes by government for primitive residents, which can refer to what one-card system has achieved, such as subsidized travel passes for taking public transport, entering museums and libraries, and enjoying public services and social benefits.

Update: Provide historical residents with life conveniences by updating facilities, and retaining and developing schools and hospitals to create a more vigorous community.

Creation: Create more space for neighborhood communication among historical residents and maintain traditional neighborhood relationships. For example, provide gathering areas for historical residents which should be restricted areas so as to create a relatively quiet community with authenticity.

Expected results: The historical residents' living environment can be improved while obtaining economic benefits with more acknowledgement about tourism.

4.2 Instructive measures

Tourism projects with characteristic culture — the government is suggested to develop tourism projects with characteristic Kulangsu culture, such as related cultural projects about celebrities, buildings, religions and music by inviting historical residents who understand Kulangsu culture deeply to participate, so as to obtain job opportunities and economic benefits with cultural regression.

Proposal for environmental protection — the government ought to strengthen promotion of the importance of environmental protection by formulating specific measures and policies so as to create sound living environments for Kulangsu residents.

Expected results: The sound development momentum of projects with characteristic culture will be surely popular among tourists; and residents as well as tourists will be satisfied with the good environment so as to create business opportunities.

In order to better implement instructive measures by mastering traditional cultural values of Kulangsu, the distribution of lifestyle, religions as well as characteristic culture should be accounted for. We can see from *Figure 12.* Distributions of the comprehensive evaluations on traditional culture hotspots that there are several cultural hotspots in Kulangsu which can carry out tourism projects with characteristic culture one by one.

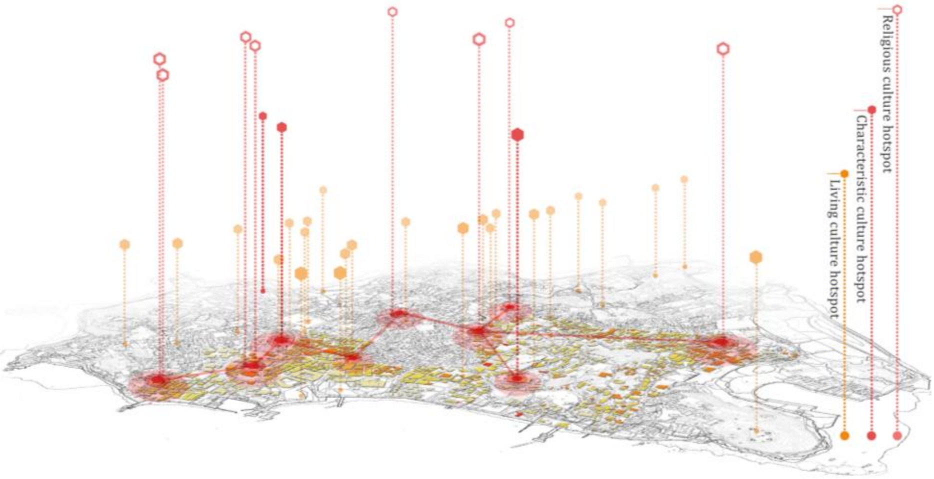


Figure 12. Distributions of the comprehensive evaluations on traditional culture hotspots

4.3 Spontaneous measures

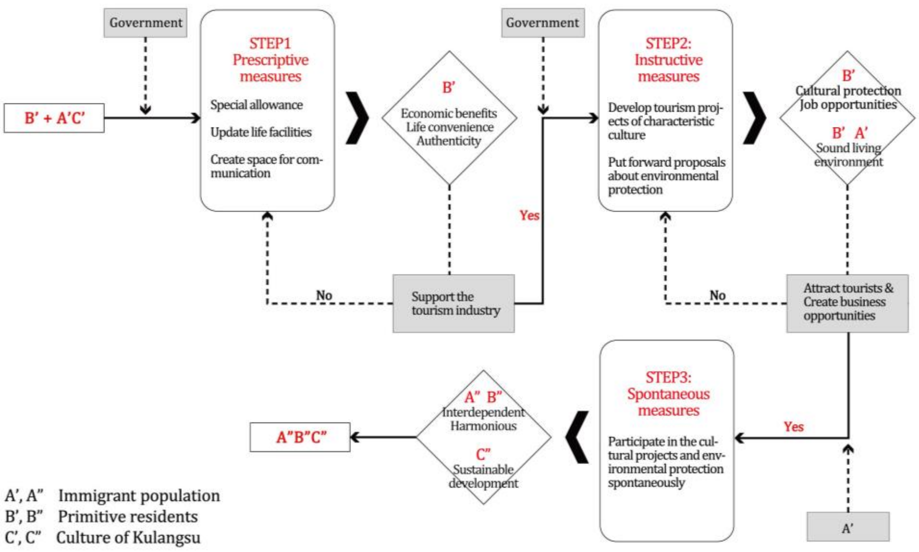


Figure 13. Flowchart of optimization strategies

Spontaneous participation — the immigrant population may organize similar activities spontaneously for benefits so that they can protect traditional culture and maintain the environment in Kulangsu voluntarily.

Expected results: Under the rational stipulation and sound guidance by government, together with the positive role of historical and immigrant residents, traditional culture protection and environment protection as well as commercial development in Kulangsu can receive sustainable development simultaneously, which results in an interdependent and harmonious relationship between the historical residents and immigrant population.

Through these suggestions, we hope there will be further alternatives and combination reactions for Kulangsu's status after displacement driven by interconnected benefits, and an activity balance so that current historical and immigrant residents can live in harmony to promote the sustainable development of Kulangsu, which was a famous historical and cultural place. The equation for the combination reaction is expressed below.

$$A'C' + B' \underset{\text{Activity balance}}{\overset{\text{Benefit connections}}{=\!=\!=\!=\!=}} A''C''B''$$

Figure 14. Visions for optimized results

5. CONCLUSION

By studying the population displacement in Kulangsu, we can see this phenomenon is a behavior of population exchange, driven by benefit during its transformation and development, where historical residents have been pushed out by government policies while external people have been pulled in for economic benefits. This is a common social phenomenon during the restructuring progress and development of historical blocks and old cities, but it usually goes toward an irreversible division condition after experiencing attraction, competition and diversification since it hasn't attracted enough value from government and the society. In terms of development in historical blocks, economic benefits and development may be achieved by population displacement, but traditional charm and pure cultural spirit may be lost. Although commercial development of tourism in historical blocks has its own values, a series of conflicts and contradictions caused by population displacement under the wider background of commercialization should be solved so as to promote the sustainable development of traditional cultural blocks.

Based on Social Exchange Theory, this paper performs a dissection of the Kulangsu Island case study examining the phenomenon of population displacement between the historical residents and immigrant population emerging from the process of tourism development in Chinese historical areas. Through analyzing the stimuli, processes and results of the phenomenon, we opine that population displacement is one of the most crucial spurs to the over-commercialization in Chinese historical blocks and the loss of original lifestyle as well as the local cultural connotations. Furthermore, the research analyzes the law, characteristics, impacts and significance of the phenomenon, and, as a result, proposes some potential adjustment and development suggestions. What the investigation has done attempts to afford fresh waves of thinking and lessons that merit attention on more reasonable, feasible, sustainable and minimally-invasive ways to protect and develop Chinese historical areas.

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Prof. Mitsuhiko KAWAKAMI
Editorial secretary: Yuanyi ZHANG

2B519, Natural science and technogly hall 2, Kanazawa Univeristy, Kanazawa
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Email: spsdpress@gmail.com

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